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MAY, 1922

THE RELATION BETWEEN RESEARCH IN HUMAN HEREDITY AND EXPERIMENTAL GENETICS

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I. Introductory

THE workers in any primarily biological science need at frequent intervals to spend a certain amount of time in considering the research methods and aims of their science with a view to possible changes.

The more their branch of science is dependent upon or correlated with other allied sciences, the more urgent becomes such a procedure.

New discoveries of a fundamental nature in one branch of science should have a strong influence on related fields. In fact, such changes, when they exist, are bound to make their presence felt sooner or later outside their immediate field, and it is the desire to assure that it be "*sooner*" rather than "*later*" that justifies the expenditure of time and effort in continually looking about for such unutilized or unfulfilled relationships.

The sooner any such relationship is recognized and admitted, the sooner can progress of a firm and lasting nature be made in both branches of research concerned.

It is with just such a relationship between the genetical aspect of eugenics and the field of experimental genetics that the present paper hopes to deal. The existence of this relationship has long been admitted, but the full scope of its extent, possibilities, and responsibilities does not seem to be completely realized at present.

In order to bring out the facts in the case more clearly, it will first be advisable to review briefly the general lines of progress in research on human heredity in the past two decades. We may then consider this progress in its relationship to the contemporary

advance in the field of experimental genetics, and in so doing bring out the need for certain changes in the methods of research in human heredity. Finally, we may outline a program of possible studies in human genetics which could be undertaken at once, be built up gradually, and eventually be utilized as the foundation of a more exact and lasting approach to our proper understanding of the inheritance of human traits.

II. The Past Progress of Research in Human Genetics

Investigations in the genetic aspect of eugenics may be said to have progressed along two main lines, or perhaps better, from two different viewpoints. On the one hand, biometrical interpretation of data has been continued by the Galton laboratory, under the direction and leadership of Karl Pearson, while, on the other hand, the search for mendelizing characters has been carried on chiefly by the American School of Eugenicists under Davenport.

The biometric school, which has avowedly used statistical methods and a non-mendelian approach to the problem, has established the *fact* of inheritance of many traits. Such publications as "The Treasury of Human Inheritance" and "Biometrika" contain the records of a great number of painstaking and meritorious investigations by this group of workers. The *type* of inheritance involved, however, remains, under these methods of analysis, obscure and unapproachable.

The mendelian school has gone farther, for, in addition to having established the *fact* of inheritance for many traits, it has been able in not a few cases to procure evidence bearing on the *type* of inheritance as well.

The exactness with which the cases of mendelian inheritance in man have been established is not, and can not be, under present methods, of the same order as that of a result based on experimentations. The question of which cases are, and which cases are not, well established is, therefore, to some degree a matter for personal opinion.

We may, however, take the opinion of a careful and conservative geneticist, such as Castle, as a fairly safe guide in estimating the number of cases of apparently mendelizing characters in man.

In his text-book on "Genetics and Eugenics," 1920, Castle lists some twenty-three characters as having been found to be mendelian, and approximately thirty-two others as either "non-mendelian" or unanalyzed. In presenting these cases there have been many publications from, or inspired by, the Eugenics Record Office of the Carnegie Institution of Washington. This institution has indeed provided funds and personnel for the great majority of the research which has procured the evidence for the type

of inheritance involved in most of the cases recorded by Castle. To a consideration of the ultimate value of this work, we shall return later. In the meanwhile one may mention such researches as those of Goddard on feeblemindedness, of Davenport and Weeks on epilepsy, of Bulloch and Fildes on hemophilia, and of Estabrook on the Jukes, to obtain an idea as to the sort of research that lies at the basis of the cases cited by Castle.

Recently the work of Mohr, on brachyphalangy, and of Stanton and Seashore, on musical ability, has continued, by methods of direct observation, the lines of mendelian analysis in as careful and painstaking a manner as the means of collecting the data have made possible. Their work represents the farthest advance in methods at the present time.

Without going into the details of the work cited, we may say that upon the rediscovery of mendelism, efforts were made by the majority of eugenicists to extend that law to humans, and that, broadly speaking, these efforts have been successful.

III. The Relation of Progress in Genetics to Eugenic Problems

While these investigations in human heredity have been under way, research in experimental genetics has been far from idle. Its progress has, in fact, been enormous, and the relatively recent developments of our knowledge as to the basis of certain hereditary characters has brought to light new genetic principles of the greatest importance.

Thus, to Mendel's original laws of segregation and of independent assortment and recombination of the genes, we find added, by the work of Morgan and his associates, linkage, crossing over, limitation of linkage groups, and the intra-chromosomal questions of interference and the order of the genes.

Obviously, these new discoveries open up a wide horizon, and introduce us to a type of detailed genetic analysis not formerly imagined. They also, however, focus our attention upon the nature of our data on human inheritance, in order to observe whether these data are sufficiently accurate to be amenable to analysis by the finer tests mentioned above.

When this question is calmly and dispassionately considered, we are forced to the conclusion that data on human inheritance, collected by the present methods, are not sufficiently accurate to justify their being used to determine the degree of linkage or crossing over, or such matters as the limitation of linkage groups, interference, or the order of the genes.

Thus, while "family histories" and reports of field workers give information of greater scientific value than data less care-

fully obtained, they have certain fundamental and unavoidable inaccuracies. For example, evidence obtained by field workers concerning the individuals who are themselves interviewed is probably fairly accurate. So, too, is the documentary evidence submitted by an individual of responsibility and intelligence concerning her- or himself. The mass of information in family records, or that obtained by field workers concerning dead or absent individuals is, however, too uncertain to use in the finer methods of genetic analysis.

It is the fact that geneticists have clearly recognized this situation, while many eugenicists have given little sign of having done so, which has brought about the existing prejudice. Such prejudice certainly exists to a marked degree and forms one of the most unfortunate but telling bits of evidence of the need for radical changes in the method of eugenic research.

There can, moreover, be no narrowness present as a factor in the situation, for the geneticist has been living in plenty and does not wish a changed attitude on the part of the eugenicist for any selfish reason. Rather he expects of the eugenicist merely a critical attitude, involving realization of the fundamental weakness in his data and steps to correct it.

While experimental genetics was in its infancy, (1905-1910), one did not hear from geneticists so much criticism against, or sense so much distrust for eugenicists. Because, however, since that time, eugenics has made little or no progress towards a truly experimental attitude we now find a real breach between these two sciences. This is most unfortunate, for they should be closely related and entirely sympathetic.

Undoubtedly the geneticists have been a bit unreasonable in expecting the immediate adoption of experimental methods by eugenicists. On the other hand, there is much to justify their attitude of criticism. Thus we find that among more than one hundred papers given at the recent International Congress of Eugenics, not one paper on human genetics introduced us to data of sufficient accuracy to provide evidence on the degree of linkage, the order of the genes, or the size and nature of linkage groups.

Another piece of evidence as to the rôle played by the work in human heredity in the advance and conduct of experimental genetics is seen in the bibliography of a modern text-book such as Morgan's "Physical Basis of Heredity." Here, among approximately six hundred references, we find less than two per cent. are to works dealing primarily with human heredity.

Evidence of this kind must not be taken as an indication that we should expect research in human heredity to prove the best field for pioneer work in experimental genetics. To do this would be

asking too much. There is, however, a serious aspect to the question when we realize that present methods in human inheritance studies will not give us the chance to utilize the definite methods of genetic analysis now possible. It is not a matter for chagrin, but involves an unfulfilled duty. If eugenics is ever to be an applied science, it must be able to predict with a fair degree of accuracy the results of individual matings. Without this, no practical system of mate selection can be suggested. Since the question of mate selection is daily becoming of more general interest, this line can not and should not be avoided. If advice as to what type of consort shall be chosen is given in individual cases under the conditions of our present incomplete knowledge of quantitative values in human heredity, we shall soon be in serious trouble. This will result if and when advice is given and followed with a markedly unsuccessful outcome. A few such cases would be sure to give the existing interest and confidence in the eugenic movement a severe and possibly permanent setback.

The non-scientific public expects great achievements and accuracy in the case of any process which is supposed to be scientific. If, however, "science" fails, they are quick to turn and rend it with ridicule and an exaggeration of its weakness. This means that those who have at heart the success of the eugenic movement, must, therefore, before it is too late, take a definite stand against overinterpretation of data within their particular field, or else be prepared to experience an ever increasing lack of sympathy on the part of the biological sciences and the educated public.

As before stated, it seems that we owe it to the future of human genetics to face the situation fairly and frankly. To do this, the fundamental interdependence of experimental genetics and human genetics has been made the keynote of the situation.

In working out a program for work on human genetics, we are faced with certain inherent characteristics of our material. The fact that these form definite limitations in some cases, forces our attention to them whether we desire it or not. In considering them, however, we shall, I think, find that the obvious disadvantages are not without some compensations and alleviating circumstances, which may easily be turned to our advantage.

Thus, while the slow breeding of mankind makes it impossible to expect or hope for the great numbers obtainable from laboratory material, and lengthens the space between generations to a somewhat disquieting degree, yet it offers opportunities of a peculiar nature as well.

For example, the long period of adolescence gives us a remarkable chance to develop to the fullest extent the study of the unfolding during ontogeny of the hereditary traits, and to weigh

with a high degree of detail the influence of such external agents as training, education, and other similar forces, upon the individual and its descendants. We can and should know our human individual—whether ancestory or progeny—in as many stages of his ontogeny as we possibly can. This is the peculiar opportunity afforded by human material. We can not ignore it by attempting a classification of our individual based on fragmentary information—but, rather, we should utilize it to the fullest extent. What might then, at first, be considered as a handicap, may with patience and careful planning be turned into a valuable asset. No insect material can give us this chance—and when we consider that laboratory mammals afford us an excellent basis for the development of methods of research applicable to humans and for a "comparative" genetic analysis—we begin to see the real possibilities of the situation.

In a somewhat similar way it has been objected that in man we can not control the matings made; this indeed is true. But if we can not control the matings, we can, at least, record them and, by finger prints and blood tests, check on data. This is no small advantage, and makes the eventual utilization of carefully collected data certain and of great value.

We have already dwelt on the inaccuracy of information based on anything short of exact tests or measurements of the individual in question—an inaccuracy which makes change imperative. As an aid in establishing and extending the desired methods of observation and recording, will come the definite cooperation of the individuals themselves, or of those controlling them, once results of promise can be shown.

The possibility of introducing some such program as the one suggested will be scouted by many—and in some cases, indeed, by those now engaged in eugenical research. Until a point of view generally similar to the one above outlined is adopted, however, we may expect that the work in human genetics will fail to carry real conviction to experimental geneticists and to the public at large.

It is entirely probable that the attitude that eugenics is or should be primarily dependent upon genetics may be seriously questioned. Should this be the case, however, it seems that a short consideration of the apparently non-genetic aspects of eugenics will bring home to us the fact that we are, even in these subjects, actually relying on genetic information before we can hope for progress.

Thus in the eugenic aspect of the immigration problem, we are faced at once with the fact that we are dealing with *race*—a fundamentally genetic problem. Racial *differences* in fecundity

and susceptibility to disease will determine just what numerical rôle any given nationality will play in forming the future population. Differences in type of mental makeup and in degrees of mental capacities from the viewpoint of intellectual achievement, moral responsibility and adaptibility to a new environment will be essential matters in determining the value of various nationalities as sources of potential citizens. The physical and psychological traits of various combinations and types of hybrids among the different European and Asiatic nations, attained under the conditions of life in the United States, will give the best possible criterion as to their permanent value as constructive elements in the formation of the future American nation.

Similarly, the question of legislation involving eugenic measures must frequently appeal to our knowledge of genetic principles as applied to man. Unless the environmental influences not transmissible to future generations can be separated from those differences that are truly genetic, we shall be at a loss to know how strict our system of segregation and confinement of criminals should be. So, too, unless we know the degree of inheritance of criminal traits in different racial combinations, we shall not know whether a similar legislative treatment of all individuals, regardless of their racial composition, is either justified or wise. So, too, in efforts to determine parentage, genetics through blood tests may be useful if properly evaluated.

Thus, in any scheme of general education along lines of eugenic measures, we are faced again and again with the fact that the limiting factor in the situation is our knowledge of the laws of genetics as applied to the particular subject in question.

In thus presenting briefly some of the factors operative in maintaining a proper relationship between genetic research in man, and experimental genetics, an effort has been made to bring out the fact that we have reached a point where a recasting of our methods of gathering data on human inheritance for this purpose is imperative.

The work in human genetics already accomplished has given results so promising that we should be able to enter a new long-time program with enthusiasm and complete confidence as to its final outcome. If we can, in this long-time program, obtain, as we go, data for *immediate* interpretation and at the same time lay the foundation on which eventually a scientific and experimental study of human heredity may rest, we shall have initiated a line of investigation worthy of the loyal support of all experimental geneticists and of the best efforts of those intimately connected with eugenic research.

IV. The Proposed Program

A. *General Considerations.*

In suggesting a program of this type, no one can be more clearly conscious than the writer, of the need for encouraging discussion and cooperation between geneticists and eugenicists before any definite scheme of work is adopted. In fact, it is probable that an "acceptance in principle" of some such outline as that here given will be sufficient action at the onset. This will give opportunity for the introduction of modifications either of methods or materials as the work progresses. Some such elasticity is necessary, for it is not humanly possible to foresee all the problems which are bound to arise.

In the main points, however, there is real hope of agreement provided the inadequacy of present methods of collecting data is frankly admitted. Obviously, the new program to be adopted involves (1) more accurate methods of collecting data as to the biological nature of both physical and psychological traits of human individuals, (2) the utilization of data so collected for three main purposes, (a) the contrasting of naturally existing different biological groups of individuals in respect to characters recordable by direct observation, (b) the building up of an ever increasing detailed knowledge, by the method of direct observation, concerning the individuals from birth to death, and (c) the continuation of this process to include the descendants of such individuals. By this means, pedigrees will eventually shape themselves which are of sufficient accuracy to be considered quite as exact from an experimental point of view as are many of those of laboratory mammals used in genetic research.

Much is heard of the unselfishness of science and its devotees, and of their willingness to sacrifice their individual capacities and efforts in the search for truth. Yet it is doubtful whether there would be even the slightest chance for the adoption of a viewpoint similar to the above unless it can be shown that the returns to be expected during the lifetime of the observer are in themselves sufficient to enlist his interest.

Fortunately, the value of the "immediate" returns is, in the case of the suggested eugenics program, so great that one is justified in considering some of them in detail, despite the recognition of the fundamental selfish element always present, which often makes a similar consideration necessary even in other cases having little or no merit.

In outlining the possible problems to be investigated, it will be advisable to keep in mind the features of particular interest to the United States. The problems of other nations will, however, be sufficiently allied to ours to make the utilization of some slight

modification of the lines of work suggested here, entirely feasible.

Bearing in mind then, that the prime requisites of the new attitude is direct observation, we must first seek to ascertain where the best opportunities for such observation exist.

B. *Opportunities and Problems.*

The chance to study human material from the various viewpoints shortly to be considered is offered at many times during the lifetime of the individual. At many of these points the information desired could be obtained with a minimum of effort and with great accuracy.

Thus, maternity hospitals, primary schools, secondary schools, colleges, city and state institutions, general hospitals (of all grades), military and naval units, factories and large commercial concerns, offices of dentists and physicians, social and church organizations, employment bureaus, boy and girl scouts, census officials, immigration stations, Y. M. C. A.'s and Y. W. C. A.'s and similar organizations are some of the points at which it would be possible to obtain data of biological value by physical or mental examinations conducted by properly trained observers.

Obviously, the earlier in the life of the individual we begin to gather the data, the more will be the genetic and the less the external contributions to its character; the earlier, also, shall we be able to recognize the initial stages in the appearance of both beneficial and harmful hereditary traits. In the former case we should be able to assure proper opportunity, physical and mental, for the exceptionally endowed individual, and, in the latter, apply at the earliest possible moment the restrictive, corrective or curative measures necessary for such deficients as might be found. The economic saving would be enormous, but even so it would be only a tiny fraction of the permanent biological benefit to the race.

Clearly, maternity hospitals provide us with the chance to observe directly the individuals at birth. Their records are, or could be made, inclusive of information concerning many physical and even mental attributes of the child. Studies on the sex-ratio, body length, weight, head form, early growth rate, incidence of abnormalities or disease are only a few of the questions easily capable of being investigated by direct observation in such institutions.

Certain of these points have already been successfully investigated in laboratory mammals or in man. As a single example of this, the variations in the sex-ratio (number of male progeny to each one hundred female progeny) may be briefly considered.

Variations in the sex-ratio are of importance economically as well as biologically. It is therefore important to investigate the various factors which underlie their modification.

Hybridization has been recognized as one such factor. R. and M. Pearl (1908) and the writer (1919) showed that in man the progeny of matings between parents of different nationalities had a higher proportion of males than those between parents of the same nationality. The same fact has been found to hold true for races of birds (Ducks, Phillips; Pigeons, Whitman, and Riddle; Pheasants, Geoffrey-Smith and Haig-Thomas; Poultry, Davenport, Pearl; and in laboratory mammals, Rats, King; Mice, Little.

In a somewhat similar way, King (1918) showed that more males proportionately occurred in the first litter among rats than among subsequent litters from the same parents, and the writer found the same to be true in humans (parents from white races and of the same nationality), when the first births are contrasted as a group with the subsequent births. This fact, for example, has a possible bearing on the popular belief that in time of war an excess of males above the "normal" ratio is produced. There might be an interesting element of truth in the popular belief, because in war time the proportion of first births in the population is greatly increased. If, now, these produce an excess of males, it would follow that this fact would be noticed and remarked on, since, at that time especially, men are at a premium.

The occurrence of sex-linked lethal factors killing approximately fifty per cent. of the male progeny in certain matings has been frequently observed in insects (Morgan and his co-workers). Evidence for their existence in mammals, (mice, Little, 1920) and in man (Little and Gibbons, 1921) has been offered. The evidence in man is statistical and can not be made more definite until our methods of collecting data have become more accurate.

The sex-ratio of stillbirths in man is a matter of the liveliest interest. On the one hand, it bears on this same question of lethal factors, and on the other, it provides important evidence on the sex-ratio at conception—and thus on the possible control of sex in mammals through the selection of one or the other type (male forming or female forming) of sperm.

So also, the sex-ratio of illegitimate births is worthy of investigation. There has been a certain amount of evidence obtained (Heape, 1908) that there is an excess of females among the progeny resulting from illegitimate births. It would be interesting in this connection to see whether the use of contraceptive methods, or possibly an unusual occurrence of endocrine abnormalities (due to the unusually high number of mental defectives among the mothers of illegitimate children) have altered the secretions of the female reproductive tract sufficiently to mean that a selection of female-forming sperm is being made, and the male-forming sperm more

frequently eliminated during their passage through the female generative tract.

In the primary and secondary schools of great cities we have remarkable opportunities for work of some of the types which we have outlined. Representatives of many different nationalities are brought together in essentially similar environment and are under almost daily observation for long periods. The chance is clearly given to study differences in mental capacity of individuals, nationalities, and races. Particular talents may be studied and many of the investigations now being made with exceptional children could be extended and supported by approach from a new angle.

The preliminary experiments of Vicari (1921) on mice have shown that F_1 hybrids produced by crossing Japanese waltzing and albino non-waltzing mice (the two parent stocks being thus from different laboratory races) made a better record in learning a simple psychological problem than did either parent race. This suggests strongly that the well known phenomenon of hybrid vigor, or heterosis, applies in the case of at least some mental characteristics as well as in physical traits.

It would be of the greatest value to compare the school records and psychological tests of children whose parents are of the same nationality with those of children whose parents are from different nationalities. Later the records of back-crosses and of F_2 hybrids could be similarly studied.

So, too, the study as to whether there was correlation between general or specific mental capacity and grade of skin color in mulattos would be extremely interesting.

Growth curves and resistance to children's diseases are other matters on which children of "hybrid" and "pure" matings could be compared. In this case, if the analogy with the laboratory mammal holds, we should expect the first generation hybrids to be clearly superior.

Other viewpoints and matters for investigation as applied to the school material would be quite as important. Thus, it has been long debated with considerable warmth of feeling as to whether first-born children were inferior mentally and physically as a group, or last-born children superior as a group, to other children as a whole. The material for settling, or at least throwing light on, this point seems to be in a condition to gather in the schools.

The effect of age of parents at the time of birth of the child, or of transference of an individual from one environment to another, of birth and rearing in the city as compared with the country, are all of them interesting and contrasted points of view that may be investigated profitably and economically.

It is also, at least theoretically, possible that by the extensive use of mental tests, methods may be devised for recognizing the carriers of recessive feeble-mindedness. If this were actually accomplished, the value to the community would be enormous.

C. *Training of Observers.*

We must not send out as observers individuals who look for anything except accurate, concrete, and unbiased data. There must be no reliance on "hearsay" or "reported" evidence of any type. The judgments as to any individual's traits or abilities, physical or mental, must be recorded as standardized measurements from direct observation. In this way, any mistakes of methods or technique will become evident at the earliest possible moment, and modifications can thereupon ensue. If the "field worker report" type of information be relied on, we shall have inaccuracies continually introduced by the varying personal equations of both the observer and the observed.

The acceptance of this last general point means that a large body of observers capable of and interested in taking accurate observations must eventually be trained and organized. The need of some such body of trained observers should not, however, prove any source of worry to us. The idea of training eugenic workers for the specific purpose of research is already in practice.

At the present time, field workers so trained are sent out to collect data from a critical point of view without, in many cases, ever having performed an experiment in animal genetics. This seems to be one of the points on which genetics and eugenics clash sharply. There would perhaps be real hope for reconciling the two if such field workers had been given a laboratory course in genetics, or if they merely went out to measure and record by standardized methods certain mental or physical traits of individuals by direct observational methods. In this last case, training in accuracy, and some knowledge of each field worker's "individual error" would be indispensable.

But the training of specialized field workers, or "field observers" as they might perhaps be called, is expensive and is only one of the ways to go about gathering data based on measurements. There are in addition two great groups of individuals, either or both of which might easily be specially trained, and who could, in the course of their professional duties, obtain data of the utmost scientific value. These are medical men and the teachers of primary and secondary schools.

A properly planned and executed lecture course with demonstrations would give the average medical student some ideas on the gathering and recording of biological data. This would suffice

for arousing his interest and at least introduce him to the genetic point of view. Individual researchers in eugenics or organizations conducting eugenic research could then arrange with medical men for the joint interpretation of the data which the medical man had gathered.

The same principle could be followed in the case of school teachers in whose training a course on the biology of their material, and on means of recording data could most profitably be inserted.

The suggestions as to the training of medical men and teachers, as well as to the modification of the functions of the eugenic field worker, are all of them based on essentially the same principle. This involves the clear separation of the function of *collecting and recording of data from its final interpretation,* unless all the collectors and observers are, in the highest degree, trained in scientific methods and thought in either genetics, general biology, or both. They should confine themselves to the mechanical and, in so far as possible, impersonal work of gathering data in the form of permanent, records, obtained from standard tests under direct observation.

With data of this type we should find the experimental geneticist becoming more frequently interested in a problem of human genetics than he ever can be under the existing methods.

In colleges as well as in other educational institutions, the employment of observers to collect and record data will result in educating the general population of the institution in the problem under consideration. The whole scheme will undoubtedly work out on the basis of compound interest and result in a steady increase in the numbers and efficiency of workers.

The value of collecting data in large business concerns or factories is also clear. Here one will be able to gather information as to efficiency under certain performance tests, as well as on the general mental attributes of accuracy, consistency, and industry. Psychological tests of the type of those in use in the army are already in a state of development sufficiently advanced to be of great value.

D. *Conclusion.*

The program as outlined is admittedly incomplete and in tentative form. Generally speaking, it utilizes natural gathering places of people at all ages, and by a continuation (with certain modifications) the training of eugenic field workers, together with the training of school teachers and medical men, it plans to interest an ever increasing group of observers who will gather by methods of direct observation, data on human genetics.

It proposes to decrease to a minimum, or to abandon, except for

the preliminary work, methods of pedigree study as at present practiced, and by the processes outlined above to replace it gradually by pedigrees more nearly comparable in their degree of accuracy with those obtained by experimental geneticists working with mammal material.

It proposes to collect data on such subjects as birth, length and weight, head form, sex-ratio, rate of growth, susceptibility to disease, incidence of abnormalities (morphological and physiological), mental capacity, specific and general, age at maturity, as well as the variations commonly recorded such as hair color, shape, eye color, skin color, et cetera.

Furthermore, as indicated above, any and all of these points may be analyzed on the basis of contrasting the progeny of relatively pure (inbred) and hybrid (outbred) matings, of first births as compared with subsequent births, of young parents as compared with old, of negro with white and other racial types, of country bred parents with city bred, of college graduates with non-college graduates, of parents who were first children compared with those who were not, of brunettes versus blondes within any particular nationality, of parents suffering with various diseases as opposed to those not so afflicted, of births out of wedlock compared with legitimate births, of parents from tropical climates as compared with those from temperate or arctic, and eventually of children born to the same parents in one climate compared with those born from the same parents in a new environment.

The above plan has its justification in the belief that under the present methods the breach between eugenicists and geneticists will become wider and wider, and without it eugenics will not be able to utilize the existing genetic methods of analysis and so maintain its place among the truly experimental sciences. Because the permanent welfare of the eugenic movement is at present prejudiced, a radical and immediate shift in viewpoint on the part of those directing eugenic research and thought is urged.

By looking ahead to the time when the pedigrees built on the new plan are beginning to take definite form, we can rest assured that there will be ample reward in the shape of information sufficiently accurate to warrant a detailed program of "mate selection" work at just about the time that the public as a whole is ready for it, and in an approach to the problems of human heredity in a way not now possible.

In the meantime, we shall have accomplished a great amount of research of direct biological and economic value to our country, and shall have laid a firm and respected foundation for research in human genetics throughout the world.

MENTAL AND PHYSICAL CORRESPONDENCE IN TWINS. II

By ARNOLD GESELL, Ph.D., M. D.

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III. The Basis of Correspondence and Disparity in Twins

The problem of resemblance in twins is one of critical significance. If we could solve it with any completeness even for one pair of duplicate twins, we should thereby gain much insight into more general problems of heredity, development and education. Dr. Morton Prince has called double personality a veritable gold mine for the study of psychological phenomena. Duplicate twins represent double personality in a different but no less pregnant sense.

Individual differences among unrelated human beings are almost infinite in variety. We do not expect even two leaves from a forest to be exactly alike; much less human beings. Persons prominent in public life often have a double; but the degree of identity will usually not bear very close inspection. Very rarely indeed do police bureaus find cases of even apparent physical duplication among criminals and crooks. A remarkable and authentic case, reported from the U. S. Penitentiary at Leavenworth, Kansas, relates of two colored prisoners, Will West, No. 3426, and William West, No. 2626, whose photographs and Bertillon measurements as well as names were strikingly alike, and who with their hats on were almost indistinguishable. But even this resemblance proved to be superficial, and did not rest on any developmental identity.

The question of correspondence and disparity in twins involves, of course, the deeper problem of the genesis of twins. It can not be said that this problem has been solved. Biologists have for some time accepted a classification of human twins into two distinct types: (1) fraternal twins, who may or may not be of the same sex, who show ordinary sibling or fraternal resemblance, and are presumably derived from two separate eggs (dizygotic); (2) duplicate twins, who are always of the same sex, closely resemble one another, and supposedly originate from one fertilized egg only (monozygotic). The existence of both types of twinning has been indisputably established in the lower animals. There can be little

question about the occurrence of dizygotic (biovular) twinning in the human family. There has, however, been some question in regard to the frequency of mono-zygotic twinning; and the possibility of reconciling specialization of resemblance and disparities in co-twins with this mode of genesis. Biologists and embryologists, however, continue to recognize two distinct types of human twinning. Obstetricians have adopted the same distinction, and maintain that it is usually possible by an examination of the placenta and foetal membranes to determine whether any given pair of twins was mono- or bi-oval in origin.

Thorndike, as we have seen, seriously doubts whether twins represent two distinct modes of fertilization and genesis, and thinks there is no need of it, whatever, to explain the facts of the likeness of twins, "for the closest likeness grades off gradually into notable difference as one ranks twin pairs by their resemblance." (Figure

From Thorndike's Measurements of Twins. Archives of Philosophy, Psy. and Sci. Methods, Vol. I, p. 44.

FIGURE 13. THE FORM OF DISTRIBUTION OF RESEMBLANCE IN TWINS

13) He admits that there is an increase in the resemblances of children born at the same time over ordinary siblings; but thinks it is due to a reduction of variability among germs produced at the same time. In his series of twins, he found that even the most similar twins differ markedly in some traits. This specialization of resemblance he holds disproves the existence of the identical-twin species. "The most identical twins will in *some* respect be less like each other than ordinary siblings." His argument is summed up as follows:

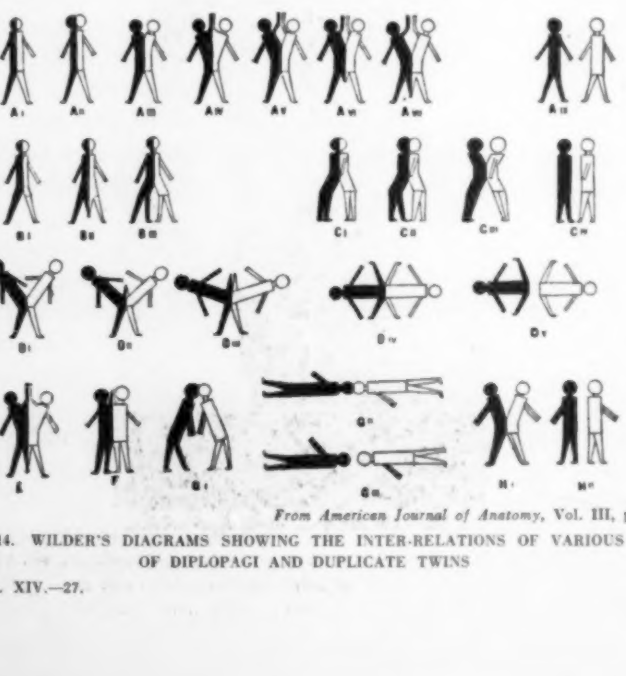
> The objections to the genesis of any considerable percentage of twins by the development of two individuals from one ovum after fertilization are: first, this specialization (of resemblance) which is well nigh universal; second, the non-appearance of any such well-defined group of especially similar twins; third, the fact of triplets, all three as identical as any two twins; fourth, the too great frequency of close resemblance.

Let us consider some facts regarding the development of twins, which may perhaps diminish or divert the force of these objections.

Bateson has given us a very broad conception of twinning in his formula "the production of equivalent structures by division." He regards it as a fundamental manifestation of life. "When I look at a dividing cell, I feel as an astronomer might do if he

beheld the formation of a double star; that an original act of nature was taking place before me." Cellular division, as such, is not twinning; but the tendency of the divided or repeated parts to assume symmetrical relations may be so regarded; and this tendency is an almost universal feature of biological mechanics. The fact that the experimental embryologist can bring about the growth of a paired structure by a simple wound of a single limb bud reveals the fundamental nature of twinning. Of similar significance is the fact that Loeb produced a 90 per cent. increase in twins by a simple immersion of his experimental eggs in lime-free sea water, which caused the segments of the living eggs to fall apart as they were formed. Newman, likewise, regards the phenomenon of twinning as a "very fundamental process almost universal in the field of biology. For wherever we have bilateral doubling, we have twinning in some form."

From this point of view every bilateral individual may be conceived as being morphologically a pair of twins. This view is so legitimate that it need not be called paradoxical. The human individual is undoubtedly derived from a single fertilized cell. He is monozygotic in origin. From this zygote, through a process of symmetrical division, develop all his right and left hand homologous organs and the right and left halves of his "unpaired" organs and structures. He is a product of developmental duplicity. Now in the case of true, complete monozygotic twins, this process of duplication has been carried to such a degree that two offsprings



From American Journal of Anatomy, Vol. III, p. 473.

FIGURE 14. WILDER'S DIAGRAMS SHOWING THE INTER-RELATIONS OF VARIOUS SORTS OF DIPLOPAGI AND DUPLICATE TWINS

result from the single ovum. A perfectly symmetrical bilateral individual on the one hand, and a perfect pair of duplicated individuals on the other represent the ideal extremes of the process of twinning. Between these extremes there are many gradations and deviations, some of them benign, other monstrous, in charac-

From Gesell's Hemi-hypertrophy and Mental Defect, Archives of Neurology and Psychiatry, Vol. VI, p. 409

FIGURE 15. A CASE OF HEMI-HYPERTROPHY. AGE 13

ter. Instead of a full twinning of the whole body, there may be twinning of various parts or only of one part. For example in the type of twinship known as *diprosopus diopthalmus*, described by Ballantyne, "the size of the head and the presence of two noses may be almost the only signs of duplicity."

Wilder's diagram, reproduced in Figure 14, shows graphically some of the numerous interrelations of diplopagi and duplicate twins. We should, I think, add the condition of hemi-hypertrophy to this series. Hemi-hypertrophy would be represented by a drawing in every respect like the normal figure A1, except that one half would be portrayed as definitely larger than the other. Hemi-hypertrophy is a total unilateral enlargement of one half of the body. This rare anomaly may be interpreted as an atypical or imperfect form of twinning,—a variant of the same process which may produce a double headed monster, or a completely symmetrical individual. Sometimes the disparity of the two sides of a hemi-hypertrophic individual is so great that there will be eight teeth on the enlarged side when none have erupted on the other; as though the individual had two physiological ages, or as though he were two different, conjoined hemi-creatures! Careful measurements of a case of hemi-hypertrophy, studied by the author when the subject was 13 and 20 years of age, showed that the mild gigantism was a permanent condition and involved apparently the whole right side. (Figure 15.) The right half of the nose was larger, the right nares twice that of the left in diameter, the right palpebral fissure was wider; on the same side the cheek and lips were fuller; the arm was larger, the right hand was relatively more enlarged than some of the other structures; the right leg and foot were similarly enlarged. On palpation the hypertrophied side had a more doughy feel than the left. This suggested redundancy of the subcutaneous tissue, but the roentgen rays showed that the bones themselves had participated in the hypertrophy. (Gesell, *Op. cit.*)

Davenport regards size or stature as a unit character of inheritance, subject to mendelian principles; but this does not assist us in interpreting the curious stature anomaly embodied in hemi-hypertrophy. We are probably dealing with some quantitative imbalance in the processes which normally determine symmetry and twinning.

Newman has made suggestive researches into heredity and organic symmetry in armadillo quadruplets. He has noted some cases in which one lateral half of the body has quite a different number of scutes from the other half, and one of these halves resembles the maternal condition. Since each set of quadruplets

have the same genetic constitution in as much as they arise from one zygote, he concludes that some irregularity in the mechanism of the mitotic cell division is responsible for the anomalies of symmetry. This factor is by no means a simple one. "Now in the armadillo there are many evidences of a system of symmetry common to all of the quadruplets, upon which has been superimposed a secondary symmetry system between twins. This in twins is more or less obliterated by a tertiary symmetry between the antemeric halves of the single individuals."

R. G. Harrison discusses rules of symmetry in his monograph "On Relations of Symmetry in Transplanted Limbs." This study is based on 462 cases of grafting of limb buds in amblystoma punctatum. He agrees with Morgan that the potential factors of symmetry reside in the constitution of the egg. "It is the intimate protoplasmic structure that underlies symmetry." Likewise reversal of symmetry. "As an alternative to the hypothethis of rotation, we might consider reversal as due to reversal of molecular asymmetry according to analogy with the behavior of optically active compounds." "There is an analogy between the production of enantiomorphic limbs and the production of situs inversus viscerum, as effected by Speemann. (Speeman obtained a large number of twins in Triton by constricting the eggs in segmentation stages or in early blastula. In many of the cases one individual, usually the right, developed complete situs inversus viscerum.) Either the reversal may be due to reversal of the intimate structure, or it may take place in spite of the intimate structure through the direct action of mechanical factors on the individual parts of the differentiating system." (*Journal of Experimental Zoology,* Vol. 32, p. 1.)

Another form of asymmetry, no less startling than hemi-hypertrophy is that of gynandromorphism. A gynandromorph is an animal that is male on one side and female on the other. This differentiation may include the reproductive organs, gonads and ducts. Usually it is longitudinally bilateral, but it may be antero-posterior. This curious phenomenon is most frequent in insects but has been reported in birds and in a few mammals. A beautiful case was described in a mutillid wasp in which the male half of the body was black and winged like the male while the female half was a rich red and wingless.

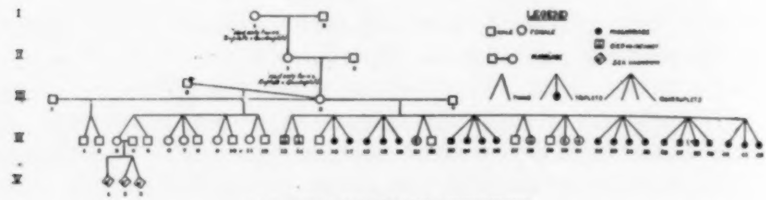
The problem of gynandromorphism has been extensively studied by T. H. Morgan and C. B. Bridges and reported in their contributions to the genetics of Drosophila Melanogaster. They found one gynandromorph among every 2,200 flies. The authors consider a gynandromorph to be a hybrid whose genes are carried by the sex

chromosome; and they give definite evidence that the peculiar sex mosaic condition is due to an elimination of one X chromosome, usually at some early division of the segmenting nuclei.

The asymmetry embodied in hemi-hypertrophy and even in gyandromorphism is benevolent when compared with the deformities and monstrosities that may occur in the field of pre-natal pathology, where one twin becomes a mere parasite upon its normal cotwin. The germinal conditions may have determined an entirely normal pair of twins, of equal partnership in the rights of life. But in all single ovum (monozygotic) twins there is always a certain area of the placenta in which there is an anastomosis between the two vascular systems of the pair of embryos. If the balance of power between the two uterine inhabitants is equal; and if no marked positional or physiological preference is given to either one, this partial community of blood supply carries no penalty. But a stronger or favored embryo may appropriate an increasing monopoly of blood, so that the sibling foetus degenerates into an acephalic, acardiac, trunkless or amorphous parasite. Here, as Ballantyne remarks, nature "attains to the extreme limit of teratological expression." One twin may be relatively normal, but the cotwin dwindles developmentally into a vegetative mass of malformed, or unformed tissues.

This glimpse into the teratology of the subject shows that twinning actually expresses itself in two apparently contradictory end results. It may produce perfect symmetry and mirror imagery; or it may produce gross disparity. Nowhere in the study of man do we find such complete duplication of individuality as among monozygotic twins; and nowhere do we find also such profound and monstrous degrees of individual difference as among twins of monozygotic origin. In this biological sense the range of individual difference is incomparably greater among monozygotic twins than among unselected pairs of individuals; for we must include among the former those aberrant foetuses which are so extraordinarily grotesque that they have lost all semblance even to the embryonic human form.

It must be recognized that dizygotic twins may undergo secondary fusions in the developmental period and be born as conjoined twins; but true double monsters are placed more readily in the monozygotic category. Wilder holds that there is a close relation between duplicate twins and double monsters; of the type in which one twin is a degenerate parasite upon the other, and also of the lightly conjoined type of twins, who can sometimes be severed successfully by a surgical operation. Newman agrees with Wilder in the view that these are all monozygotic in origin, and



PEDIGREE CHART FOR FIVE GENERATIONS

The diagram above illustrates a remarkable record of "a woman who, in three successive marriages, has never had a single child at a birth." A history of this case shows that there have been multiple births in each of four successive generations. The propositus who is indicated by No. 3 in the third generation (III-3) was married three times. (Fig. 16.)

From the Journal of Heredity, Vol. 10, p. 383.

FIGURE 16. A CASE OF HEREDITY TWINNING

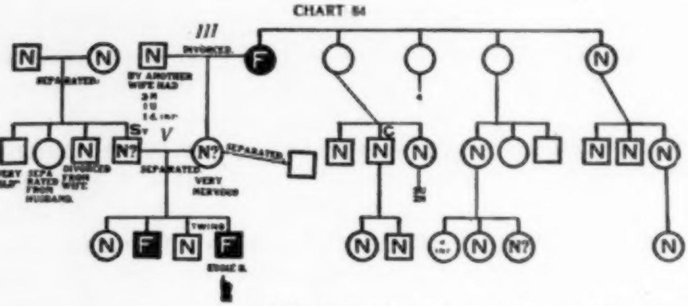
asks the question, "What more natural, therefor, than to infer that separate twins which are of the same sex and strikingly alike are also monozygotic?" Parenthetically it may be stated that Newman has definitely established the fact that armadillo twins are monozygotic in origin, and that twinning is a specific hereditary character in this species.

The problem of physical and mental resemblance in dizygotic twins is more simple. Dizygotic twins must be considered merely as two contemporaneous individuals. As a class such contemporaries doubtless show a higher degree of psycho-physical resemblance than non-contemporaneous siblings, but in any given pair we must be prepared to find ordinary fraternal individual differences. Such twins usually look no more alike than ordinary brothers and sisters, are easily distinguished by physical, mental and temperamental characteristics. (Figure 17.) Indeed one such

From Journal of Heredity, Vol. 10, p. 402.

FIGURE 17. FRATERNAL (DIZYGOTIC) TWINS

Their mother writes, "They are so utterly unlike in every way that it is hard for any one to realize that they are twins."



From Goddard's Feeblemindedness, its Causes and Consequences

FIGURE 18. FAMILY CHART OF TWINS, ONE MENTALLY NORMAL, ONE FEEBLE MINDED

twin may be mentally normal while the cotwin is backward or even feeble-minded. Goddard made a study of the family histories of 327 feeble-minded individuals. Fifty-one of his charts recorded the birth of twins. In four of these cases, one of the twins was mentally normal and the other feeble-minded (Figure 18). Surprising as this may seem to those who make the term "twin" snyonymous with resemblance, it is not difficult to explain. Two separate ova were in each case probably fertilized by separate spermatozoa. In one case both gametes were defective, in the other only one or neither. There is no reason to expect duplication or identity under such conditions of conception.

A few cases of twins have been reported in which one child was normal and the other of the mongolian type of mental deficiency (Figure 19). Mongolism is characterized by a small rounded

From Journal of Am. Medical Asso., Vol. 78, No. 1. (Dr. Stafford McLean).

FIGURE 19. MONGOLIAN IDIOT AND NORMAL TWIN SISTER AT 6½ MONTHS

skull, hypertrophied tongue with enlarged circumvallate papillæ, oblique almond eyes, and frequently lax joints, broad, flabby hands and feet, defective circulation, and nearly always imbecile mentality. Mongolians look so much alike, it has been remarked, that they appear to be members of the same family. However, Mongolians themselves do not beget children and the cause of the condition is very obscure. If the cases of one Mongolian in a pair of twins have been correctly diagnosed and reported, it suggests that the twins were dizygotic and the defect one of specific hereditary transmission. If it represents an endocrine disturbance, it may be that the endocrine defect itself was germinally determined. It is, however, necessary to be cautious in conclusions on this point. I have, myself, seen a pair of mentally subnormal, duplicate twins, pupils in a special class, who presented physical and mental features intermediate between true mongolism and the simple clinical variety of feeblemindedness. How shall we explain these semi-mongol or mongoloid types in presumably a genetically identical pair?

The necessity of caution in interpreting the rôle of chromosomes and hormones in asymmetric twins is well warranted by the confusion which associated itself with the rationalization of the freemartin. The freemartin is well known to cattle breeders as a sterile twin, born cotwin to a normal male. Professor Newman credits F. R. Lillie with having solved this baffling and controversial mystery. "Lillie's work has revealed the true nature of the freemartin; it is a sterile female whose gonads remain in the juvenile stage so that they resembles testes, and which has certain secondary sexual characters of the male due to the presence for a considerable period of male hormones in the blood borrowed from its male cotwin. The animal is hermaphrodite only in a very limited sense. The work leaves no question as to the dizygotic origin, not only of opposite-sexed, but also of same-sexed bovine twins."

If hormones play a regulative rôle in prenatal development, it might be argued that the interchange in blood supply made possible by the vascular anastomosis in the placenta of monozygotic twins, would tend to exert an equalizing influence upon the foetuses.

The term mongolian has just been used in a clinical and not an ethnological sense; but it indirectly recalls those instances in which twins actually present racial disparity rather than resemblance. This amazing possibility rests on the well recognized occurrence of super-fecundation, in which one impregnation is after a brief interval followed by another and the mother gives birth to dizygotic twins. Under illicit conditions there may be two fathers,

From Journal of Heredity, Vol. X, p. 428.

FIGURE 20. IDENTICAL TWINS FROM JAPAN, YEIICHI AND YUJI OGATA, OF TOKIO

of not necessarily similar race, for the pair of twins. Dr. John Archer, the first man to receive a medical degree in this country, reported a case in which a white woman was delivered of twins, one white and the other mulatto.

We are, therefore, confronted with an extraordinarily wide gamut of quantitative and qualitative diversities in the field of human twinning. The factors which bring about these diversities are not only germinal, but post-germinal, genetic and developmental. Their combined action may help to obscure the bi-modality of the distribution curve for twin resemblances, but leave unimpaired the validity of a classification into the two traditional groups.

It must be remembered that there are wide variations possible within either of these groups. Neither process works with iron clad rigidity or uniformity. For example, Williams recognizes that single ovum twins may be produced in one or all of as many as four different ways: 1. By fertilization of two polar bodies. 2. By premature separation of one or more blastomeres from a segmenting ovum. 3. By cleavage of the embryonic area. 4. By double gastrulization of the blastodermic vesicle. Moreover we must recognize the indisputable occurrence occasionally of an ovum with double germinal vesicle (two nuclei). Boveri has suggested the additional possibility,—actually demonstrated on eggs of sea-urchins and bees—that a sperm may occasionally unite with only one half of a precociously divided ovum, leaving the other half to develop parthenogenetically (Danforth). Recently Professor R. S. Lillie has suggested that the process of development is

basically regulated by some physiological influence of a repressive or inhibitory kind comparable to chemical-distance action, which is indeed essentially a form of bio-electric control through potential-difference. We have already noted the existence of purely nutritional and hormone factors in the developmental period; and we have Newman's general observation that in human twins, "twinning is by no means a single fixed process, but is highly variable, evidently beginning earlier and being more complete in some cases than in others."

Now these various suggestion do not suddenly clarify the problem of correspondences in twins, but they do make more intelligible the distribution of correspondences and disparities which is actually found; and they do not necessitate the denial of a relatively frequent occurrence of monozygotic twinning.

From Journal of Heredity, Vol. X. p. 409.

FIGURE 21. TYPICAL DUPLICATES

Very pertinent to the whole question of resemblance of twins is Newman's theory of somatic segregation. The conception of specialization of resemblance is dependent, of course, upon some kind of unit character method of hereditary determination; but Newman holds that although every character has a genetic basis in the zygote, "the exact expression of character is dependent upon developmental or epigenetic factors that vary in each individual case."

For this reason there may be disparities between two sides of an individual, disparity even in the friction ridge patterns of his two hands; or a disparity in stature as we have noted in our case of hemi-hypertrophy. Such asymmetries are expressions of differentiation through somatic segregation.

"The unilateral appearance of an inherited unit character, such as a friction-skin pattern, almost certainly implies some unilaterality in the somatic distribution of the differentiating factor for this character. Whether the character appears in one or in both of a pair of twins (which are genetically equivalent to the right and left sides of a single individual), or, finally, whether it appears in one, two, three, or four of a set of armadillo quadruplets, depends on whether the differentiating factor is distributed during the earliest cleavage in a unilateral or bilateral fashion; in other words, whether, with respect to the differentiating factor in question, the earliest cleavages have been equational or differential."

In brief, the early somatic divisions in the genesis of twins may be fully as important agents in segregating unit characters, as are the germinal division which characterize the maturation of the gametes. Specialization of resemblance in twins is consistent with this view, but it is also quite consistent with a monozygotic interpretation of twins which reveal numerous fundamental correspondences.

The statistical facts concerning specialization of twin resemblance investigation will serve as a wholesome deterrent of rash generalization; but they should not prevent us from recognizing thoroughgoing similarity when it actually presents itself. After all, an accumulation of numerous specialized resemblances with a few exceptional disparities, in two paired individuals, amounts practically to duplication.

To a clinical psychologist who is so constantly impressed with the differences which obtain both among normal and abnormal individuals, it seems almost like a violation of the laws of nature to find in one afternoon two personalities which are practically indistinguishable. From the biological point of view, however, there is

no reason why such instances of almost complete duplicity should not occasionally occur. The germinal and the somatic determinations of development may be so nicely balanced during the period of conception and cleavage, that we may have two persons who, psychologically as well as morphologically, stand for but one individual to the pair. Of the case of A and B, described in the foregoing pages, Shakespeare might again have said, "The apple cleft in two is not more twin than these two creatures."

AUTHOR'S NOTE: The reader of this article may be acquainted with an interesting pair of twins. The author will be grateful to receive any letters or photographs, bearing on the problem of physical and mental resemblances in twins. He is particularly interested in developmental correspondences observed in infancy and childhood. Address: Yale University, New Haven, Conn.

LATENT LIFE, OR, APPARENT DEATH

By Professor D. FRASER HARRIS
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TO the ordinary person nothing seems easier than to be able to distinguish between life and death, or to be less abstract, between a living animal and a dead one. A child can tell a dead tree in the woods when it sees one. A person naturally thinks of the entire organism as alive, the signs of its life being that it is warm, that it breathes, that its heart beats and that it is aware of its surroundings, all of which is in sharp contrast with the cold, still, unconscious corpse in which the beating of the heart has ceased for ever.

If asked to say whether an animal lying in the road was alive or dead, we should at once try to arouse it, stimulate it as it is technically called, and if, on its receiving the stimulus—a shout, a pin-prick, a touch with the boot—the animal jumped up or turned over, you would at once say it was alive; if it failed to so so, you would assume it was dead. In physiological language, an animal on being stimulated if alive will respond in some way or other, if dead it will not. Exactly the same reasoning applies to the isolated tissues, heart, muscle, etc., of the body; if they are alive they respond to stimulation, if dead they do not.

Response or reaction to the environment is then the great criterion of life; this property of being able to respond to a stimulus is called affectability or irritability. A dead organism having no affectability, fails to respond to stimulation; it is dead to the world. Response to stimulus is the chief test of livingness whether of individual, organ, tissue or cell.

Now we can state quite precisely the differences between a living animal and a dead one, for at present we are leaving plants out of account.

A living animal organism is characterized by the following capabilities or powers:

(1). It can feed, that is assimilate to itself material (food) chemically often quite unlike the composition of its own tissues, for cannibalism is not exactly a common custom. This digestion and incorporation involves excretion, or the getting rid of material

useless or injurious to the organism. The one word "metabolism" covers all the changes wrought on matter by a living being.

(2). It can transform the potential energy of food into the kinetic energy of heat (animal heat), movement, nerve-energy and electric current. A living organism under this aspect is an energy-transforming machine.

(3). It is able to resist infection and, within limits, all agencies tending to compromise its integrity. It can manufacture anti-bodies, as they are called; they are biochemical responses to biochemical insults.

(4). The living body has a life history; it has birth, youth, prime, senescence. In other words, it goes through an orderly sequence of irreversible phases. Every living thing springs from an egg or ovum, which, being duly fertilized, enters on a course of evolution or progressive unfolding of its tissues from the simple to the complex, from the few to the many, from the immature to the mature. The living being is never stationary; it has time relations. It is interesting to note that amid this constant change of material, the personality or identity of the organism is maintained.

(5). Finally, it can reproduce itself: clearly all organisms that are to survive must be capable of reproducing their like. Except in the lowest forms, where buds can be cast off and thereafter attain to the likeness of the parent (asexual method), the method is the sexual, which requires the congress of two physiologically different individuals, the male and female parents from whom proceeds the new organism.

None of these things can a dead organism do; it can not feed, nor excrete nor produce heat; it passes through no sequence of events, it can not reproduce itself, and finally it putrefies. Death, then, is the permanent impossibility of exhibiting the characteristics of vitality; it is an irreversible state. In the author's terminology, death is a state of infinite physiological inertia, the biological antipodes of affectability.

Livingness is exhibited not only by entire organisms but by their constituent tissues and cells. For tissues and cells can feed, excrete, produce heat and electric current, give rise to anti-bodies, and, finally, produce new elements. The reason for the life of the entire individual is that each of its ultimate constituents is alive.

In judging of the livingness of isolated organs, tissues and cells we must have some convenient method capable of being followed out in the laboratory. The signs of life in the laboratory are, for instance, in the case of muscle—it absorbs oxygen, it gives out carbon dioxide, it produces heat, it twitches or contracts, and finally it can evolve an electric current.

Of all these signs of life, the one mentioned last is by far the most delicate, for tissues which have long since ceased to exchange gases with the atmosphere and even to produce detectable heat, can still give an electric current on being adequately stimulated. The isolated heart of the frog or tortoise, for long after its gaseous exchanges and heat-production are imperceptible, can yield distinct electric currents to that sensitive instrument, the galvanometer. Even after the heart has ceased to beat, as far as the unaided eye is concerned, it can still spontaneously evince electric disturbance; tissues other than the heart of course need first a stimulus. The evolution of electric current is, then, the most delicate sign of life, and it is also the last sign.

But it is also the first sign of life, for Professor A. D. Waller, the English physiologist, has shown that the hen's egg will give an electric current just as soon as the almost invisible speck representing the future chick is constituted on the surface of the yolk. Such widely different things as brain, liver, heart, muscle, eye, seeds, green leaves, fruits and sea-weed will, on being stimulated, produce an electric current. These currents are of course of very feeble voltage; only in electric eels and other fishes are they so powerful as to cause the death of other animals. The electric current, since it is producible as soon as a being can be said to be alive at all, and since it can be recorded long after every other sign of life is gone, has been picturesquely called the alpha and omega of animate existence.

Now it is clear that there must be *degrees* of livingness in tissues, for, whereas some like liver and heart are intensely alive, others such as the upper layers of the skin have little vitality and yet others—enamel of teeth and horn of nail and hair—are absolutely dead. Thus when Horace said "non omnis moriar" he was not even altogether alive.

It is similar with entire organisms; we can construct a scale of all degrees of livingness from the great physical and mental vitality of a Helmholtz, a Gladstone or a Kelvin at one end, down to the somnolent stupidity of the country yokel at the other. Furthermore, vitality undergoes diurnal variations, being at its maximum at about ten o'clock in the forenoon and at its minimum between 3 and 4 o'clock a. m., a time when it is well known those who are moribund usually die. Napoleon, whose saying that an army marched on its stomach is based on sound physiology, used to say that what concerned him was the state of a man's courage at 4 a. m.

Compare the degree of vitality enjoyed by a eupeptic young man just returned from a holiday with the depression of the hopeless sufferer from melancholia. In melancholia all the tissues are

demonstrably less alive, less oxygen is absorbed, less carbon dioxide excreted and less heat evolved.

Dr. Waller has shown that a green apple gives on stimulation a more intense electric response than a ripe one, for the excellent reason that it is younger, less mature. But that it not all: if the green apple and the ripe one be very nearly killed by having had sent through them a very violent electric stimulus (shock), both apples for a time will be unable to show electric current but the young apple will revive sooner than the the older one. The analogy with human beings is surprisingly close.

Medical thought at the present time is greatly interested in that other sign of vitality, namely, resistance to infection, the power of making anti-bodies of which the class called anti-toxins is the best known.

New vegetables and animals can enter into a certain state in which, although they are not showing any of the ordinary signs of life, they are nevertheless not dead: this state is called latent life. The only sign of livingness exhibited in latent life is the electric current of Waller: in all other respects the organisms or tissues may be regarded as dead. They are taking in no oxygen, giving out no carbon dioxide, evolving no heat and are performing no movements, so that the condition is also called apparent death. A dried seed is a good example of this condition; it seems dead, but the ordinary person can ascertain whether or not it is dead by planting it in the ground and waiting until it has or has not produced a plant. If it produces a plant it was alive, but we have lost our seed, although we have gained a plant. Similarly, to know whether an egg is alive(impregnated) or not, "wait and see" if it hatches; if it does it was alive, but again we have lost our egg if we have gained a chick. Waller's method with seeds or an egg is to send a strong (electric) shock through it; if it produces an electric response it is alive. Not only has Waller used the electric response as a sign of life, he has also made it a quantitative measure of the degree of vitality. He selected a number of seeds of Phaseolus from one to five years old and tested one of each age for the production of electric current. The responses in fractions of a volt were for the five years respectively—0.0170; 0.0052; 0.0043; 0.0036; and 0.0014—a very remarkable demonstration of the statistical aspect of livingness. The older the seed the less the response; it is what one would have supposed, but it could not be taken for granted.

These seeds were dry, they were to all intents and purposes dead; they were lying in a pill-box doing nothing vital, but they were not dead, they were in latent life; they could germinate and

they could produce electric current. Drying is an excellent method for sending many living things into la vie latente. It used to be asserted that wheat found in mummy cases could germinate. Mariette, the Egyptologist, definitely denies that this wheat can do so; placed in water it becomes a clayey pulp. It is true, however, that seeds of the gorse have germinated after being 30 years in latent life; seeds, after 87 years in a herbarium have sprouted, and seeds kept for 200 years have actually produced plants. Becquerel, the French naturalist, submitted the seeds of wheat, mustard and lucerne to the following drastic treatment—having perforated the seed-coats, he dried the seeds in a vacuum at 40° C. and sealed up the seeds in a tube almost exhausted of air for one year, submitted them to the temperature of liquid air (minus 198° C.) for three weeks and of liquid hydrogen (minus 250° C.) for three days and then placed them on moist cotton wool, when they germinated! Some fairy tales are not so interesting as this.

But it seems that even animal organisms can enter into latent life. Ever since 1719 we have known this, for the Dutch naturalist, Leeuwenhoek, found minute animals called Rotifers dried up in mud apparently dead but able to live again when moistened with water.

This rising as it were from the dead is called Anabiosis. Besides the Rotifera, or wheel-animalcules, other minute animals the Tardigrada, or bear animalcules, the Anguillulidæ, or paste-eels, and some kinds of thread worms are all known to be able to survive extreme degrees of desiccation for as long as twelve years. These animals are in a state very closely resembling death, but it is not death for it can be recovered from. Death is the permanent impossibility of living again; it is an irreversible state which latent life is not. From death Science knows no recall, no resurrection, but from latent life it does. From it an organism can either go back to full life or on to death. Latent life rather than sleep is the image of death.

Obviously, only simple or lowly animals can live after being dried up; and yet the wheel-animalcules are not so extremely simple seeing that they have a nervous system.

A much more widely applicable method of sending organisms into latent life is that of cooling them. By abstracting their heat, a large number of very different sorts of plants and animals can be so devitalized as to become apparently dead; that they are not dead is known only from the fact that on being thawed they can evince the usual signs of life.

The bacteria, the simplest of all plants, show extraordinary resistance to refrigeration, for it has been proved that they can

be frozen down to the temperature of liquid air and yet retain their vitality. The late Professor MacFadyen chilled certain disease-producing organisms down to the temperature of liquid air and made them so brittle that they could be powdered up in a mortar, but after all this severe treatment it was found that on being thawed, they had retained all their disease-producing properties. The bacteria of putrefaction have been frozen at the temperature of solid alcohol and have yet on thawing retained their full capacity to cause putrefaction. These frozen bacteria were evidently not dead but only in latent life. The fact that the "germs" of decomposition of meat can be sent into latent life by being frozen is taken advantage of in the commercial process of cold storage. The beef is dead and, as we all know, liable to putrefy unless it is frozen. Were there no germs of putrefaction on the meat it would not putrefy; but it does not "go bad" on its journey from the Antipodes because the germs of putrefaction on it are by the refrigeration sent into latent life. That they are merely in suspended animation and not dead is proved by the familiar fact that as soon as the meat is thawed out, it will "go bad" with great rapidity which means that the bacteria on it and in it have returned to their active vital condition of fermenting or decomposing the meat.

Recent research on the preservation of fruit in refrigerators has shown that the spores of the Black Spot fungus can be kept for six months at minus five degrees centigrade and yet germinate at ordinary temperatures. It is a curious fungus, for its optimum temperature is as low as zero centigrade. The whole problem of the storage of fruit is being studied in the light of recent work in Biology. Fruits—apples and pears—pulled off the tree and kept for some time are still alive; in fact they are still breathing, that is taking in oxygen and giving out carbon dioxide; they are not dead, they are not even in latent life. They are not dead because, for one thing, they are not putrefying, and in fact their tissues and ferments are still too active to permit of them being described as in latent life. They are, as everyone knows, ripening, and this consists in their ferments forming sugar out of un-sweet materials. By being chilled, however, fruits can be brought into latent life which is evidently the condition to have them in if storage for a long time is desired.

Apples keep best at one degree centigrade; freezing the fruit destroys it because it breaks up the structure of the living cells and kills them and so prepares them for active decomposition. Of course, to freeze a solid mass like an apple requires a temperature lower than the freezing point of water (0° C.). Apples are found

to live best, that is "keep" best in an atmosphere containing more oxygen and much more carbon dioxide than does the ordinary air.

Coming now to the animal kingdom, we find that by the application of cold many organisms can be sent into latent life. Sir Ernest Shackleton has reported that in the South Polar seas there are certain lowly marine organisms frozen motionless in the ice for ten months in the year, but able to swim about actively for the other two. They pass alternately from life to latent life, from apparent death to life; they have a yearly anabiosis. As one might expect, the cold-blooded animals survive degrees of refrigeration which would kill the warm-blooded. Physiologists know that snails, water-beetles, insects, frogs and fish can withstand temperatures so low that warm-blooded animals would be killed outright.

Sir John Franklin in his Polar Expedition of 1820 reported on carp fish frozen so hard that the intestines of some of them could be taken out en bloc, and yet that others of the same batch of fish revived and moved actively when thawed before a fire. Fishes frozen in a block of ice at minus 15° C. have been known to survive although the bodies of some of their companions were so hard they could be powdered up along with the ice. A fish has been frozen in a block of ice, then sawn in half along with the ice and each half has, on being melted, performed active movements.

The louse (Pediculus) has been known to be alive after no fewer than seven days submersion in freezing water. The frog is an animal that can withstand being frozen without being killed. It is possible to exhibit at the beginning of a lecture on physiology a frog frozen so stiff that it can be held out horizontally by the toes like a piece of board and yet, on allowing the frog to thaw, to show that it can skip about before the end of the hour like any other healthy animal.

On the approach of winter frogs descend into the mud at the bottom of the pond and there rest in latent life until next spring; this is their form of hibernation. In all probability they are not frozen stiff, but their life processes must be at an exceedingly low ebb. Snakes behave in a similar manner.

The French scientist Pictet has stated that frogs can endure a temperature of minus 28° C. This seemed to the writer so very low a temperature for frogs to live through that he made a number of experiments on the subject to gain further information.

He found that frogs could be frozen stiff as regards their skin and muscles and yet remain alive inasmuch as their hearts were still beating although probably not carrying on an efficient circulation of blood. It was found that if ice formed around the internal organs and especially around the heart, they could not sur-

vive. It was shown that, in the case of a frog whose mouth temperature had been minus 7.5° C. for three hours, and whose heart had stopped beating, that the muscles of the eyes and of the tongue would still respond by twitching when stimulated by powerful electric shocks. It was found that the duration of chilling had an important effect, a frog whose internal temperature was minus 10° C. was alive at the end of the first hour but not at the end of the second. Temperatures lower than minus 10° C., if the frogs survived them, could have been endured only for comparatively short periods.

When we come to the warm-blooded animals, we find that, as might be expected, they cannot withstand anything like the extreme degrees of drying and chilling which the more lowly and hardy animals are able to endure. Nevertheless tissue changes can become so depressed in some of the warm-blooded animals that a state of virtually latent life can be entered upon. Such a condition is seen in the hibernation or winter sleep of bears, tortoises, hedge-hogs, dormice and marmosets. On the approach of winter these animals, having already laid on a large store of fat, retire into some place of shelter, and, ceasing to breathe, go into a deep sleep until the spring. The amount of oxygen they consume is the irreducible minimum, the heat they evolve is very small; they live on their own body-fat and other tissues, for of course they eat no food at all. When they emerge next year they are extremely thin. We learn from these cases of hibernation that even after breathing ceases, the animal may yet live; but it may surprise some readers to learn that even after the heart has ceased beating the organism does not necessarily die all at once. The fact is, many of the tissues of the body live for a long time after the body as a whole is dead. In more technical language this is local life after somatic death. Thus some muscles live for hours, and the skin and hair-roots live for days after general or somatic death. It is well known that if the face be shaved *immediately* after death, that the hairs will have grown to a perceptible extent within the next day or two. In regard to the human being, we pronounce the person dead when breathing has ceased and the pulse is no longer perceptible. The breathing may be so slight that only by the moisture of the breath condensing on a mirror can it be known to be going on. Shakespeare alludes to this in King Lear:

> I know when one is dead and when one lives;
> She's dead as earth—lend me a looking glass.
> If that her breath will moist or stain the stone,
> Why then she lives. (Lear, Act V, sc. 2).

Though the pulse at the wrist be no longer felt, yet the heart

may be alive, fluttering rather than beating in such a condition that if we could get at it and massage it, it would revive to some extent for a time at least. This possibility is now made use of by the surgeon whose patient's heart may stop during an abdominal operation. Without loss of time he inserts his hand into the wound and strikes the heart a few gentle blows through the diaphragm with the result that the heart sometimes recommences beating.

It may be now asked, can a human being enter into the state of latent life? The answer is "Yes;" but in so replying, we must recollect the kind of suspended animation which is compatible with the delicate protoplasmic structure and the complicated chemical behavior of human tissues. No mammal, no human being can be dried up or frozen stiff like some of the lowlier creatures and yet live. What we may admit is that life in man can be retained when all the vital processes have sunk to a minimum.

What is known as trance or narcolepsy is the form which latent life takes in the human being. Every now and again we hear of cases of persons, usually young women, going into profound and prolonged sleep from which they do not awake for weeks or months. During that time they take no food, they scarcely breathe, their heart's action is at a minimum. This is of course quite different from the hypnotic or mesmeric trance. Some people fear this state of trance very much; they are in dread of falling into it and being buried before they are really dead. Hence they insert explicit injunctions in their will that their physician is to open a vein or in some other way assure himself that they are dead before burial is permitted.

It is doubtless true that certain persons have been buried alive in the sense that while the heart's action was still at a minimum, they have been placed in a coffin. Stories of persons "laid out" for the undertaker, and reviving on his arrival are not unknown. Some persons have revived on the bier; but the number of persons buried while the body as a whole lived is in reality very small. Moribund persons have been buried at times of great confusion during plagues and epidemics.

Possibly the most famous case of narcolepsy is that of Colonel Townsend of Dublin which has been described by the well-known Dr. Cheyne:

> He could die or expire when he pleased, and yet . . . . by an effort he could come to life again. He composed himself on his back and lay in a still posture for some time . . . . I found his pulse sink gradually, till at last I could not feel any by the most exact and nice touch.
>
> Dr. Baynard could not feel the least motion in the breast nor Dr. Skrine perceive the least soil on the bright mirror he held to his mouth . . . . could not discover the least symptom of life in him. We began to conclude he had

carried the experiment too far, and at last we were satisfied he was actually dead . . . . By nine in the morning . . . . as we were going away we observed some motion about the body, and upon examination found his pulse and the motion of his heart gradually returning; he began to breathe heavily and speak softly.

Still more extraordinary are the narratives of the Fakirs of India who are said to allow themselves to be built up in sealed tombs for weeks without food and to be alive at the end of that time. Reports of these cases of human suspended animation are now too numerous and too well authenticated by European eye-witnesses of unimpeachable integrity to be set aside as either in themselves untrue or as due to collective hallucination.

Many people if asked to give an example of suspended animation would refer to the case of some one apparently dead through drowning. Strictly speaking a person rescued from drowning may be moribund, but not quite dead; there is, in physiological language, enough local tissue life present to ensure the living of the entire organism provided oxygen be got into the blood and so to the tissues before they utterly perish. Therefore, still speaking strictly, a drowned person is *not* in latent life, not in a condition which can be kept up indefinitely and which will pass into full life in due time. On the contrary, a drowned person is dying; but most fortunately, the several tissues do not die the moment the individual as a whole dies but can survive long enough to be revivable if only enough oxygen can reach them sufficiently soon. Of course, it all depends on the heart and nervous system; if the heart is dead the individual cannot live again; if the heart, though moribund, is capable of absorbing oxygen and of beating again, the individual will live provided also his central nervous system and particularly the center for breathing is still alive. In the actual practice of "first aid," it is well to assume that the person is alive and to persevere with artificial respiration while keeping the body warm for as long a time as two or three hours before pronouncing life extinct.

The tales of frogs being found alive in the midst of blocks of marble just broken open in the quarry have been the subject of much controversy but they are not now credited.

The latent life of isolated tissues is a remarkable phenomenon. Alexis Carrel of the Rockefeller Institute of Medical Research has actually been successful in causing tissues isolated from chick embryos to grow in glass vessels in a drop of blood-plasma for as long a time as two or three years at ordinary temperatures. When, however this "culture" was placed in a refrigerator all growth was stopped, and as long as it was chilled, it exhibited no growth, the

isolated tissues having gone into latent life. Fragments of heart muscle can similarly be kept in vitro for two or three months; these beat spontaneously during all that period but ceased beating when sufficiently chilled.

In some few cases latent life seems to be capable of being entered upon after drastic treatment with certain chemicals. The insect, the louse, is a case in point. A recent writer from Russia thus describes its powers of resistance: "The louse is one of the hardiest and most prolific pests: the majority of disinfectants and insecticides he scorns; he can survive having drops of pure alcohol or chloroform dropped on him."

The state of latent life may be regarded as a condition of high resistance towards those conditions which make for death. Abstraction of water and of heat are both of them conditions tending towards death; they involve speedy death in many organisms. But such animals or plants as can reduce their metabolism (respiration and heat-production) to the irreducible minimum may escape death in the half-way house of latent life. It is apparent death, not real death which is a condition that can *not* be recovered from. In the author's terminology, the property of affectability has fallen to a minimum, that of physiological inertia has risen towards a maximum, the absolute maximum being reached in death itself.

All poisons tend to kill protoplasm, to immobilize it; death is the complete immobilization of living molecules; whereas latent life is a degree or stage towards this end. Any agencies like desiccation or refrigeration, or reagents like alcohol or chloroform which diminish molecular mobility, tend to render life latent and thereafter to extinguish it. Upon this partial immobilization depends the efficacy of a large number of our drugs and the action of many poisons. To abolish consciousness we administer chloroform, a substance which, by uniting for a time with certain of the chemically active radicles constituting protoplasm, immobilizes more or less completely the whole molecular complex. The immobilization of the molecules of the cells of the brain has as its psychical correlative the disappearance of consciousness. The anæsthetic really tends to immobilize the brain cells, the cells of the breathing center and the heart cells; what the surgeon wants is cerebral immobilization with its counterpart unconsciousness to pain without heart paralysis which would mean death.

The organism in latent life is not dead for it is capable of manifesting once more all the vital attributes which no dead thing can do. It is however very far from being fully alive, for it may be manifesting none of the attributes of livingness save the possibility of developing a feeble electric current which can be detected

only by a delicate apparatus accessible to biological experts. It is not dead however much it looks it.

In living matter, the molecular whirl is at its intensest; in latent life the molecular whirl is for a time arrested; in death the molecular whirl has been stopped for ever. In life the dancers are in the mazes of an elaborate figure; in latent life each individual is standing stock still; in death every dancer has fallen over. In latent life the weights of the protoplasmic clock have been seized by a mysterious hand; in death they have descended to their full extent and can not be wound up again, for the cord is broken. In latent life there is only a stoppage, in death the end has been reached. In life "the sands of time" are running out rapidly; in latent life the stream has stopped; in death the sand is all in the lower globe.

In a sense very different from what the author of the lines meant it, yet in a sense profoundly true:

'Tis not the whole of life to live,
Nor all of death to die.

THE HISTORY OF CHEMISTRY IN CHINA

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THE writer recollects in attending his first course in industrial chemistry that the lecturer introduced each subject with the statement, "This substance was first discovered by the Chinese." There were but one or two exceptions to this order of service. More recent studies have caused an expression of a shade of doubt as to the truth of all these claims made in behalf of the Chinese. The people of China did early develop a skill in dyeing, glass-making, manufacture of gunpowder and fire-works, preparation of cements, etc., and this implied a knowledge of some sort of chemistry. The early Chinese knew the distinction between green vitriol and blue vitriol; while Pliny as late as the first century A. D. confounded the two. They had indigo at a very early period and used it in dyeing. They are responsible for many things long before the European world had developed a need for them; but, on the other hand, the tendency has been to consider the hoary annals of Chinese history a convenient dumping ground for disposing of clouded beginnings.

In tracing the early sources of science, it should be noted that there were three distinct centers of almost independent developments—first, India; second, China, and third, the Egypt-Arabia-Europe area which is our own. The Hindus claim responsibility for being the teachers of both China and Europe in cultural matters, but there is doubt as to the validity of their claim, and there seems little ground for believing that in the development of chemical concepts these three areas were very closely related. It is of no small importance to discover that each of these three spheres developed a similar attitude of mind toward natural phenomena and went through the same steps of growth independently.

China likewise began with an age of alchemy; this was followed by the age of the iatro-chemists. These periods in each case were somewhat in advance, chronologically, of our own. An elaborate system of medicine was developed and mercuric chloride was used as an antiseptic in surgery, though there is no ground for believing that the Chinese had any idea of the principle of sepsis. This is but one of the many examples in China where practice far out-

ran theory till theory was left hundreds of years behind. China's ancient bridge-building and canal construction are other examples. The period of the iatro-chemists held sway in China till the close of the nineteenth century, and the modern period has just begun. Two hundred years ago, China and the occident were probably at the same milestone in chemical science. It is just during the last two hundred years that we have forged ahead and the Chinese have stood still.

Age of Alchemy

The alchemists, as in Europe, began with an interest in the metals. The copper age came to China possibly a little earlier than to the occident, and the working of copper ores and the preparation of its alloys were well known at an early period. Alchemy received form as a distinct art about 1100 B. C. The important metals were five in number—gold, silver, copper, iron, tin. Lead was known but used only as an adulterant of tin so was not dignified by a place among these five. Mercury was likewise known; its common name was and is still *water silver*. These five metals for centuries and centuries were *the* metals. It is of note that in present day Chinese parlance the name for hardware store means when translated *five metals shop.*

With the five metals begins the evolution of the idea "element." The Chinese seem to have been desirous very early to reduce everything to a primary substance, to resolve all compounds into elements. Loa-dze, the Aristotle of China, dates at 700 B. C.; our Aristotle is usually dated 350 B. C. The terms "element," "original substance," etc., are frequently used, and scores of volumes in the literature of older China discourse upon the original primary substance, though with scant experimental support. The five metals were regarded as convertible one into the other; a variation of this idea makes lead a complex which may be changed under proper conditions into any one or all of these. This belief grew from the fact that the galenites of China invariably contain a good sprinkling of all these five metals.

Atomic Theory

The clearest atomic theory makes all compounds and substances reducible to a single substance which is a gas. This gas may recombine with itself and assume various forms and groupings. These are the secondary elements and one philosopher likens them to vortex rings. These now are of two kinds, either positive or negative principles. Combination between a negative and a positive may take place, and all the simple material substances are formed in this way. The theory has a flavor slightly like onr present-day

ideas of the constitution of the atom. It is doubtful whether there was any more experimental evidence in the hands of the Chinese to support these ideas than was possessed by Heraclitus with his early fire-air-earth-water theory. It is quite certain, however, that the Chinese did have more actual experience with chemical substances and with what we now call chemical industries than had these sages of ours. This theory was put into its final shape in China about the tenth century.

Gunpowder was one of the substances which the Chinese had early discovered. It was typical of substances whose action was readily explained by this theory; a certain amount of one substance was mixed with a certain amount of another, and positive uniting with negative produced the explosion.

One of the commonly used American chemistry texts makes the statement that in the eighth century the Chinese recognized that air was composed of two gases, an active gas which was termed negative and which would combine with metals, sulphur and charcoal. Moreover, it is stated that they knew that a number of mineral substances evolved this gas on heating, among which was salt peter. The writer has been unable to locate the Chinese sources from which all this information is derived. While the idea of positive and negative principles in chemical combination was a well recognized one applied to all sorts of substances, still the above statement is probably couched in modern phrases which give it more of a chemical flavor than the original Chinese possessed.

No very clear distinction, if any, seems to have been observed between compounds and mixtures, and alloys were looked upon as genuine cases of combination. Much study and experiment was directed to the bronzes. In fact, the composition of the ancient bronzes is one of the interesting topics of chemical study in China to-day. The ancient Chinese seem to have gotten it into their heads that a law of simple ratios was required for the best combinations of copper and tin, and the following comprise the "Six Ratios" from a book dated about 1000 A. D.:

Cu:Sn Ratio	Variety of Bronze
5:1	bell metal
4:1	axes
3:1	spear heads
2:1	swords
3:2	knives
1:1	mirrors

This was probably an a priori set of ratios. There may have been some experiment attached, but the theoretical ratios for the manufacture of these different bronzes was not strictly adhered to in practice as recent analyses have shown.

It is of note that zinc and antimony—and China is the present day home of the antimony industry—were identified very late among the metals. Zinc was originally confounded with lead and afterwards became known as *secondary lead* which term it carries in the spoken language of to-day. No mention of antimony is found in the old literature.

The substances derived from the metals—like blue vitriol, the oxides, etc., were all recognized as definite compounds and the Chinese also evolved a "phlogiston theory" proposing a fire element to explain this relationship. This was several centuries before the labors of Becker and Stahl! It was a very obvious method of explaining their observations, since the Chinese possessed almost none of the chemical reagents, acids, etc., which our alchemists used, and heat was the universal agent used in most transformations.

It would be impossible to even touch upon the metallurgy of the ancient Chinese. This had been made a study for centuries and had been reduced to a well-polished art. The actual methods can still be observed in use in China to-day, moreover they are essentially the methods which were in use in Europe before modern industry appeared. A modern metallurgist has suggested that the Chinese discovered the pneumatic method for the manufacture of steel at an early date, and that this accounts for the phosphorus content of the famous Shansi steels.

Age of Iatro-chemistry

Iatro-chemistry reached its high-water mark in the fifteenth and sixteenth centuries. The study of medicine had been assiduously followed by the Chinese down the ages, and the original edition of the *Ben Tsao Gang Mu,* the materia medica used at the present day, was written by old Shen Nung at about 2800 B. C. He is the Chinese "father of medicine" who corresponds to our Hippocrates of about 450 B. C. The original of this materia medica contained mention of one hundred substances. Through later revisions, it has been enlarged to include about six hundred, of which one hundred and thirty-three are inorganic substances. It was put into its present form about 200 A. D.

Many of the inorganic compounds were made directly from the metal, and considerable stress was laid on the purification of the original metals. The methods of amalgamation and cupellation had been both used since ancient times. The important inorganic compounds included blue vitriol, copper carbonate, copperas, the iron salts, tin oxide, white lead, red lead, litharge, and all the common mercury compounds. The methods by which they were made

are similar to those our own alchemists employed. All these methods in remarkable detail are to be found in this *Ben Tsao Gang Mu* which is the handbook in every Chinese drug shop.

White lead is manufactured from little lead plates by a method which is the Old Dutch process in its essential features. China and Holland did have some intercourse in ages back and the suggestion has been made that the Old Dutch process may have come from China.

Practical chemistry in China was held back considerably by the fact that the acids and alkalis, except soda and acetic acid were unknown. Sulphates were prepared by oxidation of the sulphides, and although they did not have sulphuric acid, they were able to bring about the same reactions by using blue vitriol and green vitriol at high temperatures.

Errors of Chinese Scientists

Characteristic of the Chinese "scientists" down the ages is that they lacked the inductive method. The philosophers constantly preferred a priori deduction and have reasoned everything by analogy. It seems that they truly had glimpses of the experimental method but deliberately chose the other. A group of natural philosophers arose in the eighth century, whose leader Cheng declares: "You must examine one thing to-day and another thing to-morrow, and when you have accumulated a store of facts your knowledge will burst its shell and come forth into fuller light, connecting all the particulars by general laws." If China had only taken seriously the thoughts of this school instead of deliberately discarding them, we, the occident, might be the student instead of the teacher in the modern school of science.

In addition to this, there is the spirit of inaccuracy which is one of the most real characteristics of Chinese life, which is not so much the cause as it is an attendant feature of China's backwardness in scientific matters. China has a fine system of decimal units, theoretically. But practically, while ten inches always make a foot, a foot may be one of fifty different standards, depending upon what it is that it is desired to measure, cloth, or silk, or timber, etc., and according to the standard used it may signify a length varying from 10 to 16 English inches. Distance along a road is not absolute, but depends on another factor:—is the road easy traveling,—is it through flat, or through mountainous country. A mile up hill is shorter than a mile downhill. There is a very nice practical philosophy behind some of these things, but they all point to an attitude of mind which has tended to retard a desire for accurate measurement and accurate thinking.

Conclusion

The above is but a rapid summary of some of the early accomplishments of the Chinese in the field of chemistry. The available Chinese literature has only been superficially touched. It is hoped an interest in more exhaustive studies will be roused.

It is evident that there were early minds at work in China on chemistry, and while difficult to assign dates to each of the important forward steps, it seems clear that previous to the seventeenth century China held her own, and in point of time was possibly a little ahead of Europe. It seems also true that early Chinese investigations were not more entangled with superstition and necromancy than were the European. Chemistry in China stopped growing about three hundred years ago, and admittedly the glory of past achievements fades because the Chinese failed to give their findings to the world.

THE LARGER HUMAN WORTH OF MATHEMATICS

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MATHEMATICAL thought has exercised over my spirit a fascination which is far-reaching in its effect upon my activity and happiness. It is not an easy matter to present the characteristics of this thought to one who has not been initiated into the remarkable secrets of the science; indeed the difficulty is so great that the task has seldom been attempted and not always with happy consequences. And yet I have felt that I could not fail of moderate success in this matter if I could reflect with any skill the enthusiasms of my own delight, since I believe that the fire of natural and spontaneous interest in one mind has the quality of producing a corresponding exaltation in another.

There are elements of mathematical thought which illuminate my spirit with a brilliant radiance whose after-images are pleasant to contemplate. Perhaps I can not bring to you now one of these moments of illumination of joy, for one can not produce them to order or easily recapture them but I can hope to present certain after-images which show some qualities of the original.

The impulse for the advancement of knowledge which is both most fundamental and most far-reaching in its practical and ideal effects is that which grows out of the pursuit of truth for truth's sake. What do we mean by this? What do we mean by mathematics for its own sake? It is clear that we do not intend to set up mathematics as a monster which must be worshipped, whom it is our duty to delight with the incense of human sacrifice. We mean rather to direct attention to the human values which are inherent in it apart from its use as a tool in any of the varied ways in which it may be so employed. Our purpose is to focus attention upon its primary values, those which it has in and of itself, those which are intimate to its own character and do not depend upon its uses outside of its own domain.

We are fundamentally so constituted that we delight in knowing for the sake of knowing. It is our most abstract and our most general motive in science. It actuates most powerfully our choicest spirits, moving them sometimes with a fervor akin to that of re-

ligion. A marvelous curiosity to know, insatiable and always demanding further satisfactions, creates a longing which can be relieved only by knowledge. It projects itself into the unknown and leads the researcher in ways yet untrodden to a goal which can not be foreseen. At the outer boundary line of knowledge, faint glimmerings may be detected in the darkness of ignorance beyond. What beckons us forth we do not know. Whether it can bring us any good we have no means of foretelling. It may lead us to a tragical something which will make it necessary for us, in much pain, to cast away some of our most cherished prejudices. But, whatever lies beyond in that which is concealed from our present vision,

> We work with this assurance clear,
> To cover up a truth for fear
>   Can never be the wisest way;
> By every power of thoughtful mind
> We strive a proper means to find
>   To bring it to the light of day.

Systematic and unsystematic thought. In its further reaches mathematics is perhaps the most abstruse of our mental disciplines; but in its first stages it is the simplest of those sciences which have attained permanence of result. Mathematics is the field of thought in which permanent progress is easiest. It has obtained this facility through abstraction. The problems of nature are complex beyond our ability to cope with or perceive. In the first attempt to make progress in the way of definite conquest, we must abstract from the complexity of the situation and attain to a new one relatively much simpler. In fact we may find it necessary to create a new situation having certain analogies with the actual one of nature but being so much simpler that we are able to grasp far more successfully the interrelations of its parts. It is precisely this procedure which has guided the development of mathematics.

It is not that the mathematician refuses to be interested in the immeasurable complexity of nature. It is rather that he seeks permanence of conquest, even though it be at the expense (in the first instance, at least) of a narrowed range of use. The way in which mathematics has interacted usefully with other elements in the progress of thought justifies her method of abstraction as profitable; it certainly conforms to the requirements of esthetic delight for the mathematician himself.

But the abstractions of mathematics leave us in a rarefied atmosphere too far removed from concrete experience to be a satisfactory resting-place for the mind of an inquisitive organism like

man. He seeks to get closer to concrete phenomena. But, unless he is content to deal in vague and uncertain generalities, he finds the complexity of nature far too great for him even though he has forged a mathematical tool to assist in his labors. He must still confine attention to certain groups of phenomena abstracted from their surroundings. He must try, so to speak, to lift them from the matrix of their environment. Thus we arrive at the exact sciences of natural phenomena, as, for instance, the science of mechanics, through the use of abstraction as a necessary preliminary to exact and permanent intellectual conquest.

But it is clear that we do not understand even these restricted ranges of phenomena which we have separated in thought but not in reality from their environment until we have considered all the elements in that environment and have synthesized the disjoined knowledge of its parts into a comprehensive understanding of the whole. When we come to these questions of greater complexity we feel less certain of our results and far less confident of the permanence of our conclusions. The history of philosophy with its changing systems and the flux of its emphasis is a striking commentary on the difficulty of the general problem. And even here in the comprehensive problems of philosophy itself large abstraction has already been made from the complexity of phenomena and life and existence.

In definite contrast with the systematic thought of mathematics, the natural sciences, and certain parts at least of philosophical truth and speculation, stands the unsystematic thought of art and literature. Here one deals with the actual complexity of life and even with the character of individuals and their emotions. "It is the privilege of art to represent at a glance the whole of its object, and thus to produce at once a total effect on the mind of the beholder." Not infrequently men of science have seemed to overlook the importance of this body of unsystematic thought in art and especially in literature. But it appears that the development of unsystematic thought is necessary to sanity; not that its unsystematic character as such contributes to this end, but that through no efforts being made at systematic statement one can allow the whole flux of life to be reflected at once, at least so far as to have no purposed exclusions. If one is to have the systematic exactness of pure science it can be only after many relevant considerations are shorn off and attention is fixed on a part only (usually a small part) of the whole. This is necessary to definite conquest and the method is to be freely used. If one stops with this, however, a one-sided unbalanced view results which contributes forcibly to a lack of sanity in outlook and general judg-

ment. With the continued development of systematic thought, let us encourage and support the free development of unsystematic thought in poetry and other forms of literature and art. The latter have abiding qualities of intrinsic human worth which science can never replace.

The domains of systematic and unsystematic thought have usually little effect the one upon the other; and yet between these two great arteries of our culture there must be somewhere a vital connection. The historians of general thought have not yet properly taken into account the vast body of unsystematic thought in the literatures of the world where for millenniums it has awaited their research. Nor on the other hand has the poetry of exact truth been written nor have its cultural elements in any representative case found their way into the general thought of mankind.

Literature not only takes the complex whole of life at a glance but it also internationalizes its local subjects and gives them a value which endures independently of time and place. Mathematics and poetry lie, if not on, at least not far from the extremes, the one of systematic and the other of unsystematic thought, and thus are about as far removed as possible one from the other. And yet they have a very striking common property, namely, the property of permanence. No other large domains of thought than mathematics and literature have acquired large bodies of truth retaining their values essentially unimpaired for two thousand years, not in a stagnant state, but in a state of vitality and effectiveness. It is a matter of great inspiration to see the Greek geometry and the Greek tragedy surviving through the ages and retaining the active power to excite our admiration and increase our happiness to-day.

The language of exact truth. Communication to others requires the previous construction of a language having the requisite flexibility. If we look into the remote origins of our culture we shall find reason for believing that it was language which initiated the marvelous release of the powers of man inherent and undeveloped in our primitive ancestors and coming to their fruition only after many ages of progress. It was and is a fundamental element in accumulating and retaining the heritage of the past so that each new generation, in periods of development, is able to begin a little further on than the preceding one.

There is something subtle in the way in which language makes it possible to pass the experience and thought of one generation along to the next. The phenomena of nature present themselves to us ordered in space and time, but without apparent logical connec-

tions to bind them together. As long as we meet them merely in the multiplicity of their separate existences we can not get far towards an understanding of them or of a mastery over them. It is necessary that they shall be ordered into groups or sets, each held together by some tie which serves in our mind either as a unifying or as a connecting element. The combination of distinct elements into a whole and the formation of these groups depends on a process which the mind constructs for itself slowly and only after much labor. Any means of giving a considerable measure of permanence to the constructions of one individual mind or of one age, will be of great value in maintaining mastery and effecting its further development.

Let us conceive, if possible, the condition of prehistoric man at a time when language was in the process of construction for the first time. When a tribe of men reach agreement concerning the common elements of a set of objects, as for instance the trees of the forest, and signalize a realization of their common features by giving to them some such name as tree, they crystallize into definite form a class of experiences felt by each of them in a more or less vague way. The idea denoted by the word becomes more distinct by constant recurrence and both word and idea take their places as part of the mental possessions of man.

This primitive process has been repeated in all ages of our history; it recurs often in the present day, notably in connection with the development of scientific thought. In youth we listen to the words of those of the previous generation, trace in their features some mark of the anxieties through which they have lived, and share remotely their enthusiasms and aspirations, their passions and their joys. But we receive through them in the language which they teach us a more living inheritance and a more eloquent testimonial to their ways of thought. "Unknowingly they have themselves altered the tongue, the words and sentences, which they received, depositing in these altered words and modes of speech the spirit, the ideas, the thought of their lifetime. These words and modes of speech they handed down to us in our infancy, as the mould wherein to shape our minds, . . . as the instrument with which to convey our ideas. In their language, in the phrases and catchwords peculiar to them, we learnt to distinguish what was important and interesting from what was trivial or indifferent, the subjects which should occupy our thoughts, the aims we should follow, the principles and methods which we should make use of."

A word or a way of thought into which so much experience of the race has been instilled can easily be taught to the children of

a new generation and be made to serve for them as a nucleus about which they can gather experiences of their own similar to those first embodied in the language. Thus through the various words which they use and the various turns of phrase which they employ they have a subtle means of assistance in organizing their early experience so that they are able to make much more rapid acquisition of knowledge than their ancestors who first had the confusion of unorganized impressions out of which to construct the initial organization of truth.

To the individual who is brought up in a civilized and intellectual age words and their organization into sentences certainly come earlier than clear and conscious thought. Through the use of our parents' tongue we are introduced to the complex processes of highly abstract reasoning in a manner which is truly marvelous. The way of thinking of our ancestors, preserved in some measure in the constructions of their language and in the peculiar ways of expressing thought developed through ages of progress, becomes to us our most precious heritage from the past. A highly significant part of the development of mankind is summarized into the forms and words of language in such a way as to be capable of transmission and to be of unmeasured value in passing on to the children the acquisitions of their ancestors.

What the language of daily life does for the thought of usual intercourse the language of mathematics does for the thought of exact truth. Everything which I have said about language in general I can now transfer to the language of mathematics in respect to its use in connection with exact thought. It furnishes the essential means for the expression of the latter. It supplies the support without which the mind would be unable to carry through the processes necessary to attain the more profound or far-reaching results. There is a certain storing, as it were, of intellectual force in the mathematical symbols from which it can be released suddenly with almost explosive power. These become mighty engines through the aid of which we can rear intellectual structures quite inaccessible to our unsupported power.

The invention of number was the first step in the creation of the language of mathematics; and the choice of adequate and convenient symbols for the representation of integers is one of the chief triumphs of the intellect. A long and arduous mental struggle, in which some of the finest minds of antiquity had part, preceded the conception of zero and the introduction of a symbol to represent it in the way now familiar even to our children. The result of a long and important development of thought is embodied compactly in this remarkable sign. The introduction of a symbol

like 4/5 marks a new stage in the development of mathematics. The general fact is repeated in many situations; but I can not go into a further analysis of this matter. It is sufficient to our purpose if we realize that the language of mathematics is an essential support to the mind in all its processes of exact thought and that the results emerging in this way can be expressed only in mathematical terms.

Being a lover both of mathematics and of poetry I enjoy finding certain general similarities between them. I have already alluded to one very striking common property of them, namely the property of permanence. I wish now to direct your attention to the historical fact that poetry was the primary and most important means by which the language of ordinary intercourse was brought to a stage of relative perfection just as mathematics was the essential means in creating the language of exact truth. Ordinary language having been brought to perfection by the labors of the poets was then appropriated by writers of prose; exact language having been developed by the mathematicians has been employed freely by the cultivators of every exact science.

Mathematics and philosophy. Philosophy and mathematics started life together. After a brief period of companionship they parted company and each went its own way. Mathematics was the first science to emancipate itself from the tutelage of philosophy; it gained its freedom at the dawn of Greek civilization. Mechanics next succeeded towards the close of the Grecian period, physics obtained its independent position at the opening of the modern era, biology about the beginning of the nineteenth century, and psychology in its latter half. Sociology as an independent science has hardly yet passed its period of infancy.

When men began consciously to cast about them to understand their universe, they found it possible in a relatively short time to procure and contemplate a large body of unsystematic thought, a wealth of philosophic explanation, and a rather large body of speculative proto-science of nature. But in respect of mathematical knowledge they had to begin much nearer the bottom. In the less exact disciplines there was an ebb and flow of movement with a general progress forward, accompanied often by a discarding of what at one time was considered well established. But in mathematics a conquest once made is almost never lost and there is a consequent unbroken enlargement of doctrine. Since it pushes its conquests out in many directions, is frequently annexing new domains, never yields up what it has once attained, and remains youthful in its spirit of conquest, mathematics is destined to become, if indeed it is not already, the most extensive scientific doctrine in the whole range of knowledge.

Early in the history of thought philosophy soared the heights on wings of speculative grandeur and soon reached an eminence which it has never surpassed. Mathematics took time to dig deep till it was in possession of secure foundations on which to build. Here it reared a magnificent structure of enduring beauty. In our generation this mathematics has reached forth a hand of conquest and has annexed certain restricted domains of philosophy. "The first real advance in logic since the time of the Greeks was made independently by Peano and Frege—both mathematicians" working with the tools and from the point of view of mathematics. In former days the nature of infinity and continuity belonged to philosophy, but now it belong to mathematics. An important part of the theory of classes has been annexed by this greedy conqueror.

But more than all this, it has injected its spirit into a large province of modern philosophy. Among the philosophies of the present day Bertrand Russell distinguishes three principal types, combined in varying proportions in single philosophers but in essence and tendency distinct, namely, the classical tradition, evolutionism, and the method of logical atomism. The last has crept into philosophy through the critical scrutiny of mathematics. According to Russell it represents "the same kind of advance as was introduced into physics by Galileo: the substitution of piecemeal, detailed, and verifiable results for large untested generalities recommended only by a certain appeal to the imagination."

A doctrine which lay quiescent in the domain of philosophy for many generations has recently been brought by mathematical methods into the activity of vigorous life. The modern theory of relativity is a precise physico-mathematical realization of the philosopher's speculation of relativity. The existence of the philosophical doctrine has been of profound value in the creation of the mathematical doctrine; but the latter is now so far in advance of the former that the philosopher is rare who is able to follow the train of thought by which the more exact theory is brought to fullness. This mathematical conquest of a domain of philosophy has in our generation yielded a penetrating insight into certain fundamental matters both of physics and of philosophy. A theory of gravitation, satisfying for the most part in its broad aspects, has come into being for the first time. Under the impulse of this theory our notions of force and mass have suffered considerable change and our conceptions of time and space have undergone a veritable revolution.

Without going into more detail in these matters, I may insist upon the fact that one of the profound intrinsic human worths of mathematics lies in its conquest over intellectual matters of peren-

nial interest on which agreement cannot be reached until they are penetrated by the spirit and methods of mathematics and the invariant elements of truth are extracted and justified by a convincing array of precise evidence.

Mathematics and the foundations of science. Mathematics is autonomous. What is intimate to it, its nature and structure and laws of being, must be sought in itself. Logically the mathematical sciences can be developed in complete independence of all other sciences; and when pursued in this way to their goal they completely realize their object. Owing to its self-sufficiency, its abstract character, and its exclusion of complicating factors from the ideal considerations with which it is concerned, mathematics is essentially easier than the other branches of systematic truth. The appearance of greater difficulty, which has deceived most people, grows out of the fact that it is relatively further advanced than any other subject. It requires the learner longer in mathematics than in other sciences to attain an elevation from which he may enjoy the prospect of unexplored territory. Its wildernesses are further from the confines of civilization; and the ignorant picture them as filled with horrid monsters of indescribable physiognomy. But the hardy intellectual traveler who explores in this land of the far unknown finds nature gracious, there as well as here, in dispensing her beauties and joys and comforts.

As a discipline which is unique through its being more completely developed than any other it may be utilized as an object lesson of importance in the development of thought. The mind has not been able to chart unknown regions and to explore them systematically. Truth, when attained, often has an appearance quite unexpected. Its central characteristics can not be anticipated before it appears in thought. Consequently, the extended development of any discipline affords a means of analyzing the methods and foundations of successful thinking and of extracting by such analysis principles of guidance for all domains of exact thought. In certain important respects mathematics affords just such a support to the mind in finding its way to truth; it has continuously rendered a service of this character since the days of the early Greek philosophers. This contribution has varied in detail from age to age, ranging from marvelous uses in interpreting physical phenomena to marked support in speculative philosophy and the theory of knowledge.

During the last half century or so mathematics has come definitely to a stage of self-consciousness with respect to its processes and presuppositions; and these have been analyzed and subjected to critical logical scrutiny. The foundations on which the

subject is built are understood with a completeness foreign to any other domain of thought. From this fact it may well serve as a matter of instruction to point the way to a suitable and needed analysis of the presuppositions on which any given discipline is founded.

The importance of such an analysis seems not always to be apprehended. The sciences of nature are shot through with presuppositions not recognized. Even in the more precise reasoning of mathematics there was much to be elucidated by a critical scrutiny; and certain presuppositions had to be brought into the focus of attention before it could be properly said that we understood the foundations of the science. Elsewhere such analysis has been made only very imperfectly; the success achieved by mathematics in this work has not yet borne its proper fruit. It has been made clear that no science has been brought to a truly objective stage in its development until the presuppositions lying back of it are perceived as such and the grounds for making them are clearly realized. In the sciences of nature this process is more difficult than in mathematics; this, indeed, accounts for the fact of earlier success in mathematics than elsewhere. But when the result is once achieved in one science no other should rest satisfied until the same end is reached in an appropriate way.

Mathematics and the method of thought. Perhaps it will be agreed that we can nowhere study the processes of thought, by which the intellect reaches appropriate decisions, more effectively than in that domain where it has been most successful in attaining enduring results of significant value. If this principle is agreed upon, it is a corollary that mathematics is a field of thought which will yield us some of our most definite information as to the essential elements in the methods of clear and accurate thinking. Unfortunately, mathematicians themselves have generally been but little interested in the broad principles of method which their achievements are capable of bringing to light; they have usually been disposed to stand apart from the broader questions of a theory of knowledge, satisfied apparently with the self-sufficiency of their own discipline. Outside of their fold there has never been a group of thinkers with the requisite information and training to elicit from the body of mathematics the instruction which it is thus capable of affording. This field of promising possibility lies uncultivated while we lack those advantages which its fruitage well may yield.

It is important to ascertain the character of those regions of thought in which new methods have most frequently arisen into clear consciousness. Owing to precision of ideas and processes

in mathematics we can answer that question definitely and with considerable confidence for that discipline. New methods have usually come to light in connection with well-defined and well-restricted problems. Experience has forced upon us a realization of the profound importance of deep penetration into even the simplest matters. When a new means of illuminating them has been discovered its radiance spreads to adjacent fields and often overleaps great barriers to shed new light in most unexpected places. The connections between different elements of thought can not be anticipated successfully; it requires the event to exhibit them. The presuppositions which underlie truth become apparent gradually as we derive the remotest consequences of what is already known. For the researcher everywhere the character of the success in mathematics emphasizes the importance of detailed and penetrating and carefully analyzed investigations of basic matters.

The continuous advance in the understanding of the presuppositions of our science, the axioms or postulates on which it rests, and the resulting modifications in our views of its significance impress us constantly with the supreme necessity of the logical coherence of knowledge. No principle is thoroughly understood until all of its consequences are developed and their ramifications are ascertained. This process can be carried out only through the most searching logical scrutiny; it is desirable that the intuition shall be present in discovery, but the logical faculties should dominate exposition completely. "To supersede the employment of common reason, or to subject it to the rigor of technical forms, would be the last desire of one who knows the value of that intellectual toil and warfare which imparts to the mind an athletic vigor, and teaches it to contend with difficulties and to rely upon itself in emergencies." But when its results are once attained and they are to be put to the test of a systematic organization for determining the coherence and consistency of the parts, no glow should be permitted except that which comes from the cold light of logic.

A more deep-lying problem of the method of exact thought is brought out by the question as to the fundamental character of that mental process by which scientific truth is discovered. Natural science always proceeds in one of three ways: mathematically, experimentally, or by hypothesis. Have all these methods fundamental matters in common one with another and with the processes of mathematics itself? And, if so, are they of such sort that it is useful to the progress of science or to our delight in it to have them brought to attention? Owing again to the relatively more advanced state of mathematics as compared with the natural sciences we can consider for it, in a more objective way than for them, this

question as to the basic characteristics of the process of discovery.

Not a few mathematicians are agreed that these characteristics are summed up in considerable measure in the word invention. Some of the things in mathematics one may think of as being discovered; but others, and the more fundamental things, seem to have been created by the mind. The positive integers, for instance, were not found in nature but were created by the human spirit. After their creation many of their properties have been discovered. This relation between invention and discovery pervades most of the mathematical literature. Mathematical space has been created, not found in nature, as is shown by the fact that the mathematician has several kinds of three-dimensional space as well as numerous spaces of higher dimensions. It is true that his creative power was released through observation of the environment; but it can not be maintained that the environment dictated the geometry since in that case only one geometry could have resulted. A full analysis of the matter would carry us much too far afield, but we may assert that the process of discovery in mathematics is primarily that of invention.

This leads the mathematician to suspect that the method of exact thought everywhere is largely dependent upon invention, that the hypotheses of science are not extracted from nature but are invented by the mind through a release of its powers brought about by natural phenomena. Since one's procedure in forming hypotheses is doubtless much affected by his conception of the nature of the process it is important that the laborers in each science shall ascertain the corresponding fundamental characteristics of their processes of discovery.

If we should suppose that the advance of knowledge among the most cultivated people is in the direction of making life not worth while this would operate to destroy the part of society so affected with pessimism and the whole earth would ultimately be left to the less advanced. Thus a philosophy which makes life not worth while will have a natural tendency to destroy itself, so that it can not become permanent. That philosophy of the method of thought which results from a contemplation of mathematical progress leads to a doctrine which dignifies the process of thinking, exalting it to a place of veritable creative grandeur. It proceeds in the direction of making life worth living. It is optimistic in outlook and thus has one of the first qualities which are essential to permanence.

The invariants of human nature. Another value of mathematics is in its creation or clarification for its own use of various concepts which are afterward seen to serve as a unifying element

about which other large domains of truth may be systematically organized and the relations of fact thus be brought to clearer understanding. Everywhere we are confronted by change; nature seems to be in an eternal flux. The complexity of particular phenomena is bewildering and we should be lost in their maze if we could not find some means of ascertaining the elements of permanence in the midst of the flux. In mathematics we have the same situation freed of distracting elements and idealized in a way which makes it possible to give a rather complete analysis of the whole matter. The flux and change of nature is replaced, in the ideal situations of mathematics, by what we call a group of transformations. The elements in consideration are subject to transformation according to the laws prescribed by the group which governs the phenomena; and our problem is to determine the things which are unchanged in the midst of the general flux allowed by the controlling group; in other words, we are seeking what we call the invariants, or the invariant combinations, of the elements subject to the flux permitted by the group. This conception, vaguely present in much of scientific speculation, has been recreated by mathematics into precise form, has been clarified, and has been utilized so fully that we now find it to be true that a large portion of the whole of mathematics has to do consciously or unconsciously with the theory of invariants. The essential elements of the logical characteristics of a situation of this sort are brought out clearly by the mathematical theory. The resulting body of truth furnishes us with a model by which we may be guided in the contemplation of the elements of permanence in any changing situation.

Whatever the subject of inquiry in any domain of exact thought there are certain entities whose mutual relations we desire to ascertain. The combinations which have an unalterable value under the changes to which the entities are subjected are their invariants. It is the purpose of the theory of invariants to determine these combinations, elucidate their properties, and express in terms of them the laws which are involved in the given situation. The "laws of nature" are expressions of invariant relations under the changes occurring in nature or brought about by directive agency. Two problems concerning natural phenomena demand attention. If we know the group of changes we may demand the determination of the invariants; if we know the invariants we may demand the determination of certain (if not all) possible groups under which these invariants persist. To enforce the judgment that invariants are a fundamental guide in present day science we have only to cite the fact that the theory of relativity has been devel-

oped in intimate dependence upon and under the guidance of the theory of invariants.

To pursue this matter further would carry us too far in the direction of a study of the usefulness of mathematics in the development of natural science, a matter which we are purposely excluding from present consideration. It has been said by them of old time that the proper study of mankind is man. Our purpose keeps us closer to this problem than to the study of nature. It is a fair question to ask what mathematics has to teach us concerning human nature. What do we mean by human nature except those characteristics of individual people which are unchanged from one to another, and from age to age? Those elements which are invariant through the whole group of human beings as far as they may be brought under observation? And how shall we determine the characteristics of this human nature other than by an analysis of the invariant elements in human experience and thought?

It can not be maintained that mathematics affords the best means for pursuing this study. In fact, it is probably generally supposed that mathematics makes no contribution at all to the problem of human nature, of the invariants among the qualities of individuals; we shall attempt to show that this judgment is incorrect.

The best means of studying human nature of course arises from the usual relations of life. But these in themselves are quite insufficient for a complete analysis. The continued acceptance of a large body of vital mathematical truth through some millenniums suggests the invariant character of certain elements of human thought in its logical aspects, just as the continued appeal of ancient poetry (for instance) to people of cultivated taste bespeaks an unchanging element of human nature in its finer emotional aspects. The presence of such invariant elements, wherever they may be found, is an instructive matter for the historian of culture and civilization.

Where can one find a systematic analysis of literature, that great storehouse of material for the understanding of human nature and the progress of unsystematic thought, having for one of its primary objects the ascertainment of the invariant elements of human nature in its emotional aspects? A study of the changes in taste and their cause contributes indirectly to this end; but both literature and mathematics, in different ways and with reference to different parts of our nature, can be made to yield important values towards an understanding of its invariant elements.

Since the historian of thought and civilization is seeking to bring his analysis of the progress of culture into systematic form

it is perhaps no great surprise that he has found it difficult, and so far has not found it possible, to utilize successfully the truth which is half-concealed and half-revealed in the unsystematic thought of literature. But it is rather astonishing that such historians of thought have not been able to utilize the systematic work of mathematics in their expositions. I know of only a single instance where a general analysis of the progress of thought has taken an adequate account of the domain of mathematics, and that is in the work of J. T. Merz on "The History of European Thought in the Nineteenth Century."[1] This excellent general analysis has not had for one of its purposes to bring out the invariant qualities of human thought, and hence of human nature, as they are made manifest by the abiding truths of mathematics. The contribution which mathematics has to make to the study of human nature has not yet been considered in a systematic way.

And still it is certain to those who contemplate the nature of mathematical truth that many characteristic qualities of human thought are to be determined from such an analysis. It is a significant fact for the understanding of ourselves that the demonstrations in Euclid's *Elements* gain the same adherence to-day as in his time and in all the intervening ages; an invariant quality in the processes of reasoning and the ground for conviction through demonstration abides through the ages. There is absolute agreement in all times and all places that the number of prime integers is infinite, bespeaking a unity of the whole race in its understanding of the properties of elements conceived in the first place with exactness. The properties of a Euclidean triangle are in harmonious agreement even though they have been discovered by numerous thinkers of many generations. A sphere did nothing for the Greeks contrary to what it does for us to-day. The properties of a cube are invariant, whoever derives them and in whatever age he lives. It is an eternal truth that every integer is the sum of squares of four integers, and there is unanimity as to this fact and as to its demonstration. The persistence of mathematical theorems and the continued agreement as to their proof indicates a profound unity in the characteristic thought processes of those who contemplate them, exhibiting one fundamental phase of human nature.

Artistic delight in mathematical truth. Truth serves many ends. When a science has reached a certain stage of development,

[1] To this magistral work and to many articles in the *Encyclopædia Brittannica* I am under deep obligations in connection with this address. I have also profited by reading C. J. Keyser's *The Human Worth of Rigorous Thinking*, Columbia University Press, 1916.

varying greatly with the character of its material, it begins to throw off into the body of society great practical or even esthetic values which could not be realized without it. Astronomy has enabled us to have some conception of the vastness of space and the hugeness of the mass of matter, perhaps infinite in its totality, distributed through this space. Geology has released the imagination to contemplate enormous periods of time and, through its influence on biology, has rendered marked service in making possible our conception of the long progress of life on the planet, culminating in man. Mathematics, by exhibiting a body of truth which can live through millenniums without needed corrections, and at the same time can grow in magnitude and range and interest, has given the human spirit new ground for believing in itself and for rejoicing in its power of consistent thought.

It is not enough to accumulate the elements of knowledge or even by means of them to control nature for our use; we must appropriate them by idealizing them into things of beauty and motives to conduct. Truth may be made to yield the highest delights of contemplation in the spirit of artistic performance. This is generally realized in the case of the unsystematic truth afforded by literature and the other fine arts. It is less in evidence in the greater body of systematic truth. But when the latter is brought to its highest order of perfection, as it is in the domain of mathematics, it becomes capable of yielding the purest and most intense delights in artistic excellence. They are of a sort to be enjoyed in large measure only after an adequate training; and in that respect there is a certain exclusiveness about them. But to those who are willing to pay the price of adequate knowledge mathematics yields a gratification of the artistic sense surpassed by that arising from no other source. "The musician plays and the artist paints simply for the pure love of creation." The mathematician creates abstract and ideal truth for the pure love of discovery and of contemplation of the beauty of his mental handiwork.

In pursuing esthetic satisfactions we create a beautiful theory for the sake of our delight in it, as in the case of the theory of numbers or of abstract groups. Working in such fields with the simpler elements of mathematical thought we make progress of a sort not at first possible with the more complex materials. We bring the theory to a higher state of perfection; there are fewer lacunæ; the connections of the various parts are exhibited with clarity; we have a sense of having seen to the root of the matter and having understood it in its basic characteristics. The theory thus developed becomes an ideal in the light of which we get a new

conception of what should be attained in other fields where the labor and the difficulty are greater. Results in one field of mathematics may thus become of great value in a totally different range of mathematical ideas or even in other disciplines altogether. Moreover, when such progress is attained we often find that the tools employed in bringing it about are sufficient for dealing with more difficult matters, so that the one completed theory furnishes us not only the ideal, but also the means, for further valuable progress.

A characteristic delight in mathematical truth is that which arises from economy of thought realized through the creation of general theories. When we develop the consequences of a set of broad hypotheses we find that our results, which are attained by a single effort, have applications at once in many directions. Thus we see the common elements of diverse matters and are able to contemplate them as parts of a single general theory pleasing for its elegance and comprehensiveness.

Fundamentally mathematics is a free science. The range of its possible topics appears to be unlimited; and the choice from these of those actually to be studied depends solely on considerations of interest and beauty. It is true that interest has often been, and is to-day as much as ever, prompted in a considerable measure by the problems actually arising in natural science, and to the latter mathematics owes a debt to be paid only by essential contributions to the interpretation of phenomena. But, after all, the fundamental motive to its activity is in itself and must remain there if its progress is to continue.

"The desire for the one just form which always inspires the literary artist visits most men sometimes" and is ever present to the mathematician in his hours of creative activity. The one just form which the mathematician seeks is more ideal and perhaps more delightfully artistic than that sought by any other thinker; for it is primarily a form of abstract thought in which he is interested, a form which remains the same as ages come and go, as languages are developed and die away, as the canvas of the painter rots to fragments and the material of the sculptured image is resolved by decomposition into its elemental dust. It is a thing of beauty which is indeed a joy forever.

For many people the numerous practical applications of mathematics have obscured its artistic elegance. But it is not the only fine art which in another aspect is also of the greatest practical utility. This quality it shares with the noble art of architecture. The two equally satisfy the following informal definition given

by Sidney Colvin: "The fine arts are those among the arts of man which spring from his impulse to do or make certain things in certain ways for the sake, first, of a special kind of pleasure, independent of direct utility, which it gives him so to do or make them, and next for the sake of the kindred pleasure which he derives from witnessing or contemplating them when they are so done or made by others." Both mathematics and architecture possess all the qualities here enumerated. Each is of essential practical utility, contributing necessary elements to the material comforts of man. And, more than this, each delights the artistic sense through beauties peculiar to itself and furnishing the ideal reason for its existence.

From a certain point of view the four main divisions of thought—mathematics, natural science, philosophy, that unnamed one ruling without definite system in the domain of art and literature—are the stones and brick and mortar from which is builded the culture of the time, into which are wrought the values received from the past, and through which our development shall proceed to the acquisition of new power for further conquest. We break the environment into parts in thought and from these we fashion new objects such as never before existed in the universe—objects both concrete and ideal—and these we put together in ways well pleasing to ourselves to serve the ends we propose or erect the constructs we conceive.

But this is too mechanical to be the whole truth. The more profound values lie deeper and have their fruition only in the fullness of the character of man. If science did not touch a more profound matter than mere motion or reach to constructs which can not be adequately pictured by material symbols, it would fall far short of the glory of Living Thought. But it does forcibly react in a profound way with all our activities, particularly through the emotions excited by the play of the artistic sense. In fact, the elements of all Thought are parts of one body, living and organized, inspired by the breath of the Universe itself and pulsating with the life of truth in its deeper manifestations.

The problem of consistent thinking. The leading characteristic of man is the power to think. There is nothing of higher esthetic interest than to determine whether we can think consistently. This fundamental question can be answered in the affirmative only by exhibiting the results of consistent thinking. The existence of mathematics affords the best conceivable proof of its possibility and gives the spirit of man leave to believe in itself, since here admittedly is a body of consistent thought maintaining

itself for generations and even for millenniums, able to sustain all the attacks of logic and all the tests of the practical life.

There was a time when this confidence in the permanence and consistency of mathematics was absolute. The fundamental methods of argumentation men conceived to belong to a class of innate or inherent ideas which had been put in the mind of man by the Creator. The initial hypotheses and basic notions of a mathematical discipline they thought of as belonging to the same category. If these innate ideas did not have all the elements of absolute certainty, there could be only one conclusion: the Creator had deliberately deceived man. Since they considered this to be absolutely impossible, they had complete confidence in the certainty of mathematical results.

Nowadays we seek a more earthly reason for confidence in our constructions in science. Our agreement that mathematics is possible as a consistent body of truth we now understand to rest on postulates for which admittedly we have no logical demonstration. Perhaps these postulates may be framed in the following way: Reasoning is possible and does not lead to wrong results when employed according to the universally accepted rules; mathematical objects can be created or discovered by the mind; we can actually formulate consistent axioms or postulates concerning these objects. With each of these three statements there are grave logical difficulties. We can not assert that we have an immediate perception of them as true; we can not, by direct illumination, see their validity. We must examine each of them in the cold light of experience and accept it only in so far as it meets the most exacting demands. Our confidence can never be absolute. As J. B. Shaw has said in his "Philosophy of Mathematics:" "We may found our deductions on what premises we please, use whatever rules of logic we fancy, and can only know that we have played a fruitless game when the whole system collapses—and there is no certainty that any system will not some day collapse!"

Let us proceed further with the difficulties of the situation. In all preceding generations conceptions in mathematics have been used with confidence which, in the experience of a later day, were found to be not sufficiently well defined; they have been discarded or essentially modified, sometimes after generations of confident use. It is not likely that men have heretofore always made mistakes of this kind and that we have suddenly come upon an age in which mathematical conceptions are refined to the last point of analysis.

We are then forced to the conclusion, however unwelcome it may be, that the certainty of mathematics after all is not absolute,

but relative. To be sure, it is the most profound certainty which the mind has been able to achieve in any of its processes; but it is not absolute. The mathematician starts from exact data; he reasons by methods which have never been known to lead to error; and his conclusions are necessary in the sense, and only in the sense, that no one now living can point to a flaw in the processes by which he has derived them.

Let us make as concrete as possible the difficulties and the immense values which are at stake. Let us suppose that the Euclidian geometry should become untenable under the weight of constant accretions and should go crashing down to helpless ruin; in that day man's hope of reaching tolerable certainty anywhere in his thinking would be destroyed and even the world of mind would become a dark confusion of irrational elements. The character of such a loss suggests the magnitude of the present value.

What certainty have we that such loss does not impend? We have no logical demonstration of its impossibility; and in the nature of things can not have such a demonstration. The same uncertainty attends all other truth, and in even more marked degree. There is no logical certainty of the consistency or the permanence of truth; at most there is a moral certainty. From mathematics we have the strongest grounds for the latter. When thousands of persons through thousands of years examine thousands of theorems proved by numerous methods and in numerous connections and there is always absolute unanimity in the compelling character of the demonstration and the consistency of results, we have a ground of moral confidence so great that we can dispense with the proof of logical certainty and comfortably lay out our lives on the hypothesis of the permanence, consistency and accuracy of mathematical truth. The existence of mathematics gives the mind the best reason yet advanced for believing in its powers and the essential accuracy of its careful processes.

Emotional exaltation arising from the contemplation of mathematical truth. A profound emotional exaltation arises from the contemplation of mathematical truth either in the static aspect of accomplished results or in the dynamic aspect of a science with an everlasting urge to further development. By the ideal values which it constructs and by the permanence of its results mathematics gives to the spirit of man the right and the courage to believe in itself and to trust its controlled flights. Here it justifies its claims to preeminence more completely and more profoundly than in any other part of its broad domain. It exhibits a body of truth which is permanently pleasing and which exacts confidence at all times and among all thinkers who examine it.

By building first on its narrow and exactly conceived foundations and by adding bit by bit to its possessions of permanent truth, mathematics has made possible a release of the imagination of man such as can be completely realized to-day by only a relatively few individuals, a release however which will allow an expanse of the general human mind to-morrow or the next day. Vast new domains of contemplation are opened up by the non-Euclidean geometries, theories of hyperspace and space of an infinite number of dimensions, functions of an infinite number of variables and functions of lines. Such conquests give a new sense of power and mastery and increase the dignity of man. In the presence of so many beautiful creations of his thought "the mathematician lives long and lives young; the wings of his soul do not early drop off;" he rejoices in the grandeur of the heights to which his controlled imagination attains.

If one is to realize the intenser delights afforded by the contemplation of mathematics he must of course be a deep student of its secrets. It is only when he is able to devote a large share of his energy to research and is successful in the creation or discovery of important new truth that he may rejoice in the fullest glow of delight through a realization of himself in such ideal conquests. However important the work of preserving past discoveries and handing down to the future the accumulated tradition and however far-reaching such a stream of influence flowing in hidden ways in the minds of cultivated people, it can not be placed in the same category with that creative work which guides instructor and student alike and teaches generations what to think. It is the great glory of mathematics in our time that its achievements are being immensely enriched and extended by the researches of the present; so that this, the oldest of the sciences, has the vigor and the spring and the growth of the youngest of them. He who discovers a fact or makes known a new law or adds a novel beauty to truth in any way makes every one of us his debtor. How beautiful upon the highway are the feet of him who comes bringing in his hands the gift of a new truth to mankind!

Alone before the wild and restless force
Of nature we have seen man's active soul
Stand forth in awe without a sure resource
Of power to overcome or to control
The salient things submerged beneath the whole.
And we have seen in vision some new power
Spring up from hidden depths of mind and roll
With bounding joy to conquest, hour by hour
Increasing till the strength of man reached fullest flower.

What stage of progress have we now attained
In this process of far-unfolding thought?
What ground to think that it shall be maintained?
Have we the fullness of our conquest brought
And reached the depths where nature works and caught
From her the deepest blessing she can yield?
Or fathomed her profounder secrets fraught
With good, no major truth remaining sealed
From sight, with only minor things to be revealed?

If so, no glow of zeal could move our thought;
Our life would lose its meaning and its zest;
No vision of the future could be caught
By mind's prophetic penetration, blest
With prospect large; in pessimistic rest
And deep stagnation then must mind abide
Without a great compelling interest
To bring its power to action and to guide
Its strength to ways of joy or largest use provide.

But crescent science such a view as this
Dispels; for largest things with keen insight
We feel; the growth of knowledge must dismiss
From thought such pessimism; its darkening blight
Of shadow is illumed by sure foresight.
We joy to see new worth to be attained
And know the present conquest is but slight
Compared with wider truth that shall be gained
For thought's dominions, now by science unexplained.

We need the willing mind to consecrate
Its strength to finding truth, the zeal to bring
From nature's storehouse values good and great
And lay them at the feet of man. To wring
From restive nature some unwilling thing
Were joy supreme. The means for our release
To greater power we seek. The bounding spring
To growth shall move in us and never cease
To bring to us new joy and truth's renowned increase.

ON FOUNDER'S DAY

By Professor EDWARD L. NICHOLS
CORNELL UNIVERSITY

ON Founder's Day it is well that we should remember the founder. Even after the lapse of half a century his personality is still vivid.

To the undergraduate of the early seventies, Ezra Cornell was a familiar figure. We saw him often on the campus or in the work-shops of Sibley—a tall spare man, of shrewd but kindly countenance. Then in 1874 occurred his death. We all marched with the cadet corps at his funeral. A few of us had the privilege of standing at his bier as members of the guard of honor.

If you would get a definite picture of the personality of the founder, read those pages in the autobiography of Andrew D. White which treat of the beginnings of the university. You will be impressed in that account with two great qualities, *breadth* and *insight*.

Consider the far sightedness evinced in that incident of the choice of site for the new institution. It is a matter of record that Ezra Cornell insisted on the present spacious campus, now world-famed for its natural beauty, first among American university sites in that regard. When his first board of trustees favored a location lower down and more convenient to the village in the valley, a location ample for any school which they could imagine as likely ever to grow up on this hillside, he made his prophetic retort since become famous: "Gentlemen, some of you will see five thousand students on this hill."

Not one of them, it is safe to say, had the slightest expectation of the fulfilment of so extravagant a claim; but as we all know it has literally come to pass long since.

To us in these days when five thousand has become a sort of standard or average size for the enrollment of the larger universities in this country, there is nothing wild or improbable about Mr. Cornell's remark. But in 1868 there was no university in the land with half that number of students. Moreover, even to-day, five thousand at Cornell is a very different thing from five thousand in any town of a million people, where the local demand would fill several universities of that size.

What kind of a school did the founder have in his mind when he saw in his vision "five thousand students on this hill?" To me his well-known motto tells the story.

"I would found an institution where any person can find instruction in any study."

Here we have two great attributes specified, *Democracy* and *Breadth*. It was not the definition of a college, for the American college, then as now, was neither broad nor democratic.

Something quite different was clearly in the founder's mind—a place having at least two of the great qualities of a *university*.

With the wise and liberal cooperation of Andrew D. White, the founder succeeded in getting something quite different actually started—a place free from sectarian bias or control, where all subjects were on an equal basis; where women were on equal terms with men; where eminent scholars from abroad—men such as Agassiz, Lowell Curtis, Froude, Freeman, Bayard Taylor, Boyesen and Adler—added their influence to that of the resident faculty.

These accepted commonplaces of to-day were so far from accepted half a century ago that the new Cornell was launched amidst a hurricane of mingled abuse, derision and applause. Now, after more than fifty years, we find a growth of college and university population here and elsewhere out of all proportion to the growth of the country and a growth of material equipment even greater than the growth of the student body. Never in the history of the world have such large amounts of property been set aside for education as in American endowments within the last half century.

Comparing Cornell with other American universities, we note the almost complete disappearance of the gulf which once separated us from our sister institutions, and we can not but ask ourselves whether we have indeed abandoned the ideals and purposes of the founder or whether those great principles have commended themselves elsewhere, and the movement has been towards our position. That the movement has been this way I believe we may claim, and be proud of it, but of course we have all developed and are approaching a common standard.

Comparing American students with those of the rest of the world we notice one striking difference.

University students abroad have been identified with every forward movement—their radicalism has frequently been a source of alarm to those who stand for "things as they are."

A hundred years ago and a little more, when Napoleon felt strong enough to announce the empire, all France was subservient but the students of Paris. They in a body refused to sign the oath of allegiance to the emperor.

In 1848 when Prussia was in revolt and the throne was very near to overthrow, the revolutionary camps were full of students. A foolish, ill-judged movement it proved to be, and a very expensive one to some of them personally. But if it had carried and Germany had become a republic, there would have been no German Empire in 1870 and no world war in 1914!

Again in 1878 the situation was so serious in Berlin that mounted police patroled the streets all night in platoons. In those days the students hired public halls in the city and crowded them evening after evening to listen to orators who urged the abolition of autocracy and the conversion of Germany into a social democratic state.

Again in Russia in the early years of this century—at what terrible cost did students work for the overthrow of czardom! Russian prisons were filled with them and it seemed as though Siberian convict camps would soon contain all the intelligence of Russia. And they failed, and we all agreed that it was a foolish, futile demonstration; but again, in view of the suddenness with which the Russian government crumbled a few years later it may not have been so forlorn a hope.

Finally, consider how every now and then the student body at Tokio breaks out into protest against the government; recall that highly dramatic episode in Shanghai when a handful of students captured a gunboat in the harbor and proceeded to bombard the arsenal; also the very recent Chinese student strikes—seemingly the most harmless and footless of all forms of protest, but which are said to have brought about the resignation of at least two high officials in Peking nevertheless!

At home what do we find? Student bodies infected with radicalism? Never! On the contrary, if we are to go by what opinions are most loudly voiced and which are taken as typical; opinions by which we are judged; the American undergraduate is a tory and a reactionary. Take his attitude on any of the great questions of the day, from the status of women in the university, on which subject his view is medieval, to the league of nations.

We have just been through one of the greatest of revolutions and have dethroned a king, but I have heard of no great student outcry against King Barleycorn.

Now nobody wants a university full of anarchists. They are certainly a nuisance, harmless but still a nuisance—but since everywhere else in the world students are progressive, why not here also? "It's natural for boys to be liberals" they say in England "they turn tory fast enough as they get older."

The answer I find in one word: *tradition.*

Our vast growth in American educational institutions is after all largely social—literally millions for fraternity houses, dormitories, stadiums, etc., as against thousands (and this means a thousand to one) for the advancement of knowledge. The fraternity houses at Cornell have cost more than all the buildings on the campus (west of Bailey Hall). The student body spent on one football game this year more than the entire annual income of our new Heckscher fund for research.

Now social institutions are governed by tradition, not reason, and tradition is bad. It is tribal in nature.

In the Solomon Islands they have the canoe tradition. Before a new canoe can be put in the water, a ceremony must be performed involving a human head—an enemy's head if possible, or if not the head of a member of a neighboring village found straying from home, or the head of a slave of the tribe, or even the head of some useless member of the tribe itself. Incidentally the owner of the head is eaten, and by strict adherence to such traditions the natives had pretty well eaten each other out of existence by the time the Europeans came along and offered them more modern means of destruction.

Now most of our traditions are much like that in spirit. Such maxims as: "The king can do no wrong," "We fight it out first and talk about it afterwards," "Might makes right" are as old as the human race. All the traditions of caste, of the vendetta and feud, of lynching, of racial antipathy and above all the great tradition of war, are of savage origin.

As to the better so called traditions of fair-play, of sportsmanship and the like—they are modern and artificial. They are not native to us, but have to be acquired and are all too readily relinquished. Note the constant effort necessary to maintain a high standard of sportsmanship even in college sport; how hard to accord applause and consideration to an adversary; how easy to lapse into a primitive boorish muckerism! Are we in American student circles, and especially here at Cornell, governed by tradition rather than reason?

If what they say of us is true: That there is no scholarly interest among students; that undergraduates read nothing; that they do not think, then have we indeed departed from the great ideals of the founder. For tradition is aristocratic not democratic, reactionary not liberal, feudal or tribal in spirit, based on custom, on mere superstition, anti-rational, anti-intellectual.

Let us admit sorrowfully that the world is so near to its primitive savage state that it must still be governed by tradition, not by reason.

Of a *university* the opposite is true:

There *principles* have supplanted *tradition.* A university is essentially democratic; it lives to think and by thought; it is ever progressive not reactionary. Its chief function is the advancement of knowledge. Are we then a university, as the founder intended us to be, or not?

We are, or I should not be speaking to you to-day on this subject!

Here on East Hill in Ithaca, where Ezra Cornell planned to have it, there is a university.

"I do not speak of this great group of buildings, nor of their contents, nor of any college or group of colleges. These colleges are useful establishments but collectively they do not constitute the Cornell of which I am thinking.

Here and there upon the campus in laboratories and seminary rooms and libraries you may have become aware of individuals and groups—old and young, men and women, at work at something which does not appear in undergraduate schedules or curricula.

Theirs is the most fascinating and most important work in the world: the discovery of new truths and principles. They are adding to the world's stock of knowledge, and it is by means of this knowledge that the world is slowly—oh so slowly—getting away from its tribal traditions.

They are the university—the kind of university we may well believe the founder would delight in were he alive now.

Such work is creative and therefore immortal. He who adds a single real fact to our knowledge of the universe has won a place in the hall of fame. His recognition may not be immediate nor local, but whenever in the course of time that fact is made use of the discoverer will be remembered.

A Scottish schoolmaster a century ago made just one contribution to the science of optics. His name is a familiar one to-day to every school boy in the world who studies physics, and will be for centuries to come. He doubtless devoted a life time to teaching; but fine and beautiful and important as teaching is it is ephemeral, like newspaper work. Its influence lasts, but the source is soon forgotten.

If Cornell University should be wiped out by some great scourge or cataclysm—even as some of the European universities may yet be by the great war—it would be utterly forgotten in a single generation in spite of its great services in the teaching of tens of thousands of students. But it will not be forgotten whether it live or die, for it will have contributed something to the world's knowl-

edge. These investigators—they are of the immortals. Neither they nor their work will die. They are the soul of the university and the soul lives on. Nor will the memory of the founder die, for he made his contribution in that motto of his and though his ideal were to fail of realization and be forgotten, we can easily imagine scholars of the far future finding his saying and acclaiming:

So here was one who in the darkness of the nineteenth century had the modern idea, for he said:

"I would found an institution where any person can find instruction in any study."

To those of my hearers who are undergraduates I would say, strive to get in touch with the real university which I have described, for until you do you will not be of the university. You may be enrolled in this or that college and after four years go out with our label on you, but, unless you have taken some part, be it only that of a breathless, eager, looker-on at some one of the creative activities of our researchers and scholars, you will never get the best—the only really worth-while thing that Cornell has to offer you.

UNUSUAL HUMAN FOODS

By Professor ALBERT M. REESE
WEST VIRGINIA UNIVERSITY

IN that interesting book by Simmons, "Animal Food," published many years ago, is described almost every imaginable kind of animal food used by civilized and savage races of man, from man himself, in the interesting, if gruesome, chapters on cannibalism, down to the lower invertebrates.

It is my purpose, in this short article, to call attention only to those types of animal food not commonly eaten by Americans that I have actually eaten and proved to be palatable. Many others might, of course, be mentioned on good authority, but only those which I have myself eaten will be described. Some of these obviously could have no economic importance in the United States; others might be added to our menus, and a few are already on the market in some localities.

Let us begin with the highest group of animals, the Mammalia.

Monkeys. Owing to the strong anatomical resemblances between man and some of the monkeys, it is possible that some of the reported cases of cannibalism have been due to mistaking monkeys, which are quite generally used for food in some countries, for human infants or children. This resemblance would probably be sufficient to deter most people from eating monkey meat, if the animal were cooked entire, but if the hands, head and feet be removed and the body be dismembered, the human resemblance is lost and, unless told, the average person would not know what animal he was eating. Monkey stew or minced monkey meat would probably be eaten and enjoyed by anyone who did not know what animal was before him. As in all animals, the flesh may be tough or tender, probably depending upon the age of the monkey and on how it is prepared. Just what familiar flesh it resembles in taste it is hard to say, but it is certainly a very agreeable food.

Peccary or bush-hog is another animal that makes a very acceptable dish, though, of course, not one of any importance outside the countries where these animals occur. The flesh may sometimes be tough, but is excellent, resembling, as might perhaps be expected, pork more than anything else.

Opossum. This animal is familiar to most people in this country, but, except among the negroes of the South, is not fully appre-

ciated as an article of food. While not numerous enough in most sections to be of much importance it might be raised in captivity. Its flesh is quite pleasant to the taste, possibly resembling fresh pork as much as anything.

Woodchuck or ground-hog is a very familiar rodent in many parts of the country, being so numerous in some places as to be quite a serious pest. Why the ground-hog is not more generally eaten is hard to understand, for, when properly cooked, it can scarcely be told from rabbit. Its legs being small it does not have the fine hams of the rabbit, but there is sufficient flesh on a good sized animal to be well worth cooking. It is customary to soak the flesh in water to remove the "gamy" taste, though the necessity for this is doubtful.

Muskrats are sold in the eastern markets under the name of marsh hares, at about the same price, per pound, as rabbits. They may be cooked in the same way that rabbits and squirrels are prepared, and possibly would not be distinguished in taste, by the average person, from the more familiar animals.

Considering the enormous numbers of muskrats that are killed for their fur, this animal should be more generally used for food. The flesh is darker, before cooking, and is not so attractive as that of the rabbit, but its taste when well prepared is certainly excellent.

We Americans have many silly ideas and prejudices in regard to what is fit to eat, and it is one of these prejudices that keeps many people from eating woodchuck, perhaps because of its relation to rats and other disagreeable rodents; people do not seem to realize that rabbits and squirrels, which they do not hesitate to eat, are also rodents.

Whale meat has been used for food by the Japanese and others for generations, but it is only within a few years that we Americans have begun to realize the possibilities of these huge mammals as a source of food. It is said that there are no "choice cuts" on a whale; all the flesh is equally good. Imagine an animal from which Porterhouse steaks may be cut in half-ton chunks!

On our Pacific Coast and, perhaps, in the largest cities of the east, fresh whale meat may be bought in the markets. The writer has never tasted the fresh meat. In certain western cities whale meat is canned, and in this form may be obtained almost anywhere. This canned meat looks like canned beef, and when made into stews or cooked in other ways would probably not be distinguished by the average person from excellent canned beef. Why it is not more generally used it is difficult to understand, unless the popular idea that whales are fishes has something to do with it.

Birds, unfortunately, are nearly all suitable for human food. The writer is opposed, on principle, to the use, under ordinary circumstances, of birds as food, with the exception, of course, of domestic breeds and perhaps certain of the water fowl.

However, there is one bird, only too well known in almost every corner of the United States, that might well be an article of diet; it is the house or *English sparrow.* There is very little difference of opinion in regard to this species; it is a pest—in some places a serious nuisance—against which a nationwide war of extermination has been declared. In destroying these birds by traps or guns, why not make use of them as food? To be sure they are small, but they are nearly as large as the bobolink that was formerly so extensively used for food under the name of reed-bird. They are easily prepared, and when properly roasted taste just as good, so it seems to the writer, as the famous reed-birds. The bones are so tiny that most of them can be eaten along with the flesh. At certain seasons of the year when they congregate in large flocks it is not difficult to shoot, with fine shot, or to trap in various ways, these birds in considerable numbers. If the use of English sparrows as food could be encouraged it might help in the war to reduce their numbers.

Edible birds' nests, while of no importance in this country, form quite an important article of commerce in some parts of the Orient. In China, which is apparently the chief market, they bring fancy prices. These nests are, as is well known, formed of the dried saliva-like secretion of birds, and are of about the size and shape of the nests of cemented twigs built by our chimney swifts. The material resembles gelatine and when treated with water swells in about the same way. Properly cooked the edible bird's nest is supposed to be a remarkable delicacy. The writer prepared, according to the only recipe available, a nest obtained near the Island of Palawan of the Philippine group. The result was a gelatinous mass without a particle of taste. Either the nest was stale or there was something wrong with the method of preparation, since none of those who tasted it was enthusiastically anxious for more.

The writer once ordered bird's nest soup at a Chinese restaurant. While the taste was excellent, there was nothing but the name on the menu to indicate that the dish was not ordinary chicken soup. Besides the fine particles of chicken there were small, tasteless lumps of gelatine that *may* have been bird's nest or may have been ordinary gelatine. There was absolutely no taste other than what would be expected in chicken soup. Perhaps the soup has been Americanized to satisfy the present demand.

Reptiles. There is scarcely a group of animals against which there is such a general and unreasoning prejudice as the Reptilia, and this applies as much to their use as food as it does in other respects.

Almost anyone will eat turtles, nearly all species of which may be used for food; yet when alligators or lizards are suggested they are usually declined with disgust, often with the statement "because they are reptiles." An illustration of this was once seen in South America. The writer had expressed the desire to taste the flesh of the iguana, which lizard was said by the English gentleman, whose guest he was, to be commonly used for food. The Englishman spoke enthusiastically of the flavor of the big lizard; but when a few hours later, the writer, after skinning a freshly killed caiman or South American alligator, suggested cooking some of the flesh, this same Englishman declined, with vigorous expressions of disgust, to consider eating the crocodilian. Another illustration was seen years ago in central Florida. The individual, in this case, instead of being an educated English gentleman, was a very ignorant and crude youth, who had said that he would not be caught eating a dirty "varmint" like a 'gator. Shortly afterwards, during his absence from camp, we cooked some alligator steaks, and on his return, had them served as "fish." We all partook; the youth in question eating with evident enjoyment the despised "varmint" under the name of "fish."

The writer has described in a previous issue of this journal[1] an alligator dinner given at a boarding house in a college town, where some thirty people, of both sexes and of various occupations, ate alligator meat every individual declaring the meat to be unusually palatable. In this case the meat was cut into pieces and cooked in cracker crumbs, like a breaded veal cutlet, which it resembled somewhat in taste and texture. It is probably the silly prejudice, illustrated above, that keeps the alligator from being used extensively as a source of fresh meat in the regions where the species is found.

The use of *turtles* as food, from the lowly snapper to the aristocratic diamond-back, is too familiar to need mention here. The use of the eggs of these animals is less common, especially in this country, though in some tropical regions they are extensively used. While scarcely comparable to the fresh eggs of domestic fowls, some turtle eggs are decidedly palatable.

Amphibia. As among the reptiles, so among the amphibia, there is an unjustifiable prejudice against certain forms by people who do not hesitate to eat other species. Almost anyone will eat

[1] December, 1917.

frog legs (for some reason only the hind legs are commonly eaten, though the rest of the muscular parts are equally good), while very few people would dream of using the larger salamanders, closely related to the frogs, as food. Of course these salamanders can not be obtained in such large numbers as frogs, and, their legs being small, most of the meat would have to be obtained from their tails; but some of them are quite large, and are more or less of a pest in streams where they abound, so that it would seem a waste of good food to destroy them instead of eating them.

The *axolotl* and other moderate sized salamanders are said to be used as food in Mexico and to be exposed for sale in the Mexican markets. Perhaps the most common of these large salamanders is *Necturus,* popularly known as the *mud-puppy* or *water-dog,* though these names are also applied to Cryptobranchus or the hellbender. As necturus is rather thick-bodied and may reach a length of 12 to 18 inches there is considerable meat upon it, which in flavor is very similar to that of frogs. The animal is harder to skin than the frog, but it may be cooked in the same way, and it is doubtful if the average person would distinguish between the taste of its flesh and that of a similarly prepared frog.

Cryptobranchus allegheniensis, the American giant salamander or hellbender, popularly known as *alligator* or *water-dog* is the largest of American salamanders, reaching a length of two feet and a weight of nearly two pounds. It is found in the waters tributary to the Ohio River, in some places being quite abundant. As in Necturus the legs are too small to be of use as food, and as in Necturus the skin is rather hard to remove; but the flesh is equally agreeable and during the breeding season the eggs, of which a considerable mass may be found in a single animal, are also of a very pleasant flavor.

An illustration of the persistence of the taste of ether in an animal killed with that reagent was seen in a hellbender which after being etherized, was skinned, cleaned, washed and, after several hours, was fried in egg and cracker crumbs. In spite of the washing, the intervening hours, and the heat of cooking the flesh still retained a distinct flavor of ether, though the eggs had no such taint.

Fishes. Since nearly all of the common fishes are used for food, and there is but little popular prejudice against members of the class, attention will be called to but one group that should be more generally made use of as food: this is the *Elasmobranchs,* or sharks and skates. In the markets of China these forms are com-

monly displayed for sale. The fins, especially of certain species, are in demand as a source of gelatine.

Certain of our sharks are now canned and put on the market under the trade names "gray fish," "deep-water swordfish" and perhaps other names. While not of such a desirable flavor as canned salmon these canned sharks are excellent substitutes for fresh fish and should be more generally used. The addition which their use would make to our food supply may be seen from a statement made by Kellogg in his "The Shellfish Industries" that "It has been estimated that thirty-seven million dogfish, equal in weight to half the total catch of the Massachusetts fishermen, were taken by them in 1905."

Of invertebrates but one or two will be mentioned. Nearly everyone likes lobster, either fresh or canned, but its near relative of fresh waters, the *crayfish,* is unknown as an article of food in many regions where it is quite abundant. In certain sections of the west and south crayfish are used as food and are extensively canned, but, as has been said, they are unknown as an article of food in many places where, if not sufficiently abundant to sell commercially, they could be easily collected in sufficient numbers for family use. When prepared in about the same way that fresh lobster is cooked the crayfish makes a decidedly pleasant dish, and the mass of abdominal muscle in the "tail" of a large crayfish is considerable.

Fresh water mussels. In many of the rivers and other bodies of fresh water in various parts of the country are found several species of fresh water mussels. In some localities where they are of certain species and are of sufficient abundance they are collected and their shells are used for making pearl buttons. It may be possible that these mussels are used for food at times, but I have never heard that this is done. Owing to the frequent pollution by sewage of the streams in which they live, it would probably be unwise to eat them raw, but there is no reason why they should not be eaten after being properly cooked. They are, to be sure, sometimes very tough, but this might be remedied by special methods of cooking, and the flavor, while not so delicious as that of some of the salt water bivalves, is decidedly agreeable.

Squid and perhaps other cephalopod molluscs are sometimes displayed for sale under the name of devil-fish, by Italian stores, even at a distance from the coast. They are used in making soup and possibly in other ways.

The writer had a soup or stew made from an eviscerated specimen, using milk, seasoning with salt and pepper, and adding a

lump of butter. The flesh, while not so delicate as that of an oyster, was not especially tough, and the soup was very much like that made from oysters, but with an additional taste that was not very agreeable. Possibly the addition of celery or some other flavoring substance might counteract this undesirable taste.

This devilfish soup was given to a domestic science class of about twenty young women; about half of these young women voted that they liked the preparation, and all were interested in trying a new dish.

At thirty cents a pound it is not likely that squid will become especially popular on American tables.

The reluctance of people towards eating untried articles of food is mentioned by V. Stefansson in an article in THE SCIENTIFIC MONTHLY for December, 1920. He says: "Similarly we found that 'well brought-up' men, used in their homes to a large variety of foods, both domestic and imported, take very readily to any new thing (such, for instance, as seal meat). But men 'poorly brought-up' and used to only half a dozen or so articles of food in their regular diets are generally very reluctant to try a new food unless it has been represented to them in advance as an expensive or specially delicious thing." . . . "For one thing, the man of the laboring type has a feeling of being degraded when he is compelled to eat the food of 'savages,' while the man of the intellectual type is appealed to by the mild flavor of adventure in experimenting with 'native food.'" Stefansson found that Eskimo women were much slower to try new kinds of food than were the men.

REGARDING THE HABITS OF TARANTULAS[1] AND THE EFFECTS OF THEIR POISON

By W. J. BAERG
UNIVERSITY OF ARKANSAS

As one who has grown up north of the Mason and Dixon Line and had seen tarantulas only in collections, I had never given these big hairy spiders any serious thought. However, when I came to the Ozarks of this region and heard some of the weird stories telling how these tarantulas would jump on a person from a distance of 15-25 feet, and how their bite proved almost always fatal, I developed considerable curiosity in regard to these terror-inspiring objects. Upon learning that these spiders are fairly common on the stony hillsides near the college campus, I immediately set to work and in a short time assembled a small collection. It seemed

HOLE OCCUPIED BY TARANTULA, SHOWING THE WEB OVER THE HOLE. NEARLY NATURAL SIZE

[1] *Eurypelma steindachneri* Ausserer, determined by Professor C. R. Crosby, Cornell University.

desirable to me, since so little is known about their habits, that I keep a few alive for daily observations.

In the Ozark region the tarantulas are commonly found living in holes. These holes vary from 1½ to 2 inches in diameter and from 8 to 12 inches in depth. They are apparently not made by the spiders themselves, but are appropriated from gophers, ground squirrels and other small rodents. Most of the holes when the spiders are "at home" are covered with a thin webbing, some are merely lined around the edge.

It would seem that flooding these holes with water might be an easy way to get the spiders; but here, as elsewhere, inference is misleading. The simplest way that I have so far found is to insert a slender stick into the hole and gently tease the spider, whereupon it usually proceeds to leave the hole at once.

Having found that a large grasshopper once a week or ten days and a small dish of water solved all the problems of feeding, I encountered no further difficulties in keeping the tarantulas under bell jars on the laboratory table. During the winter the feeding problem is still further simplified, for, although these spiders remain active all through the year; yet they refuse all food from some time in October till about the middle of April, and require nothing but water for their sustenance and well-being.

HOLE OCCUPIED BY TARANTULA SHOWING WEB AROUND THE EDGE OF HOLE. NEARLY NATURAL SIZE

VIEW OF UNDERSIDE OF TARANTULA SHOWING THE BROKEN FANG. NEARLY NATURAL SIZE

One female tarantula, about 2¼ inches long, has now been under observation for more than two years, and is apparently doing very well under the simple diet outlined above.

The process of molting, or shedding the skin, seems sufficiently interesting to be briefly described here. The skin splits around the upper edge of the main body (cephalothorax) in such a way that the entire top from the base of the cheliceræ (the arms that operate the fangs) to the base of the abdomen comes off like a lid. The skin of the abdomen may or may not split along the middle of the back.

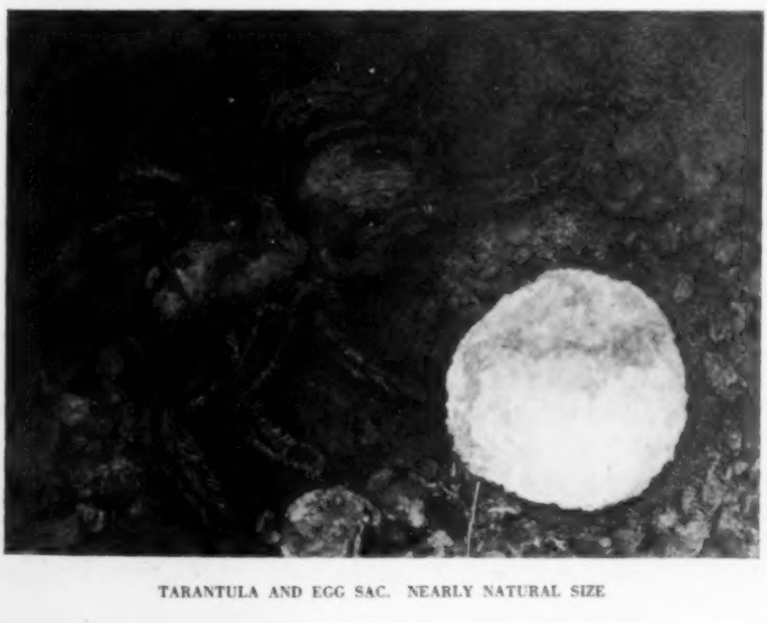
A year ago the molting took place on August 15, this year on August 20. The latter molt occurred from 8 to 11 in the morning and I was able to observe the entire process. The first conspicuous evidence of molting is the lifting of the upper surface of the cephalothorax. This remains attached over only a short distance near the base of the right chelicera.

A significant feature in the process of molting is that it proceeds practically without any visible effort on the part of the tarantula. About all that one is able to observe is that the body by rather faint pulsations gradually oozes out of the old skin, rising up and moving to the left in such a manner that by the time that all the appendages and the abdomen have been extricated from the skin the tarantula is seen lying on its side and facing in the opposite direction of the skin. At this stage the spider turns on its back and begins to exercise its legs in a more or less leisurely manner for about one hour when it gets back on its feet and behaves in the normal way.

Some time this year during the month of May I obtained a large female which was apparently heavy with eggs. Instead of placing her under a bell jar, like the others, I put her into a large battery jar half filled with dirt, thinking that she would probably make some sort of a hole preparatory to egg-laying; but she made no such an attempt.

On the morning of June 28 the spider constructed a large silken bag all around herself and kept busy on the inside of it for some time. On the next day she was on the outside of the bag which had now shrunken to the size of a black walnut without the hull. From now on the tarantula spent practically all her time sitting over the bag.

On July 20 I made a small opening in the bag and took out a



TARANTULA AND EGG SAC. NEARLY NATURAL SIZE

few eggs and young spiders. The eggs are white in color, globular and about two millimeters in diameter. The young spiders match the color of the eggs so well that they are quite difficult to see when small. The young were at this time feeding on the eggs still unhatched. A few days later, July 24, I decided to take out all the eggs and young for further study. The bag contained at this time 460 eggs in apparently good condition, 113 young spiders, and 90 eggs which were shrivelled up. This makes a total of 663 eggs as originally laid. The shrivelled eggs had obviously furnished the food for the young spiders. Hoping that I might get some information on the final result of this struggle for existence, I replaced the eggs and the young spiders in the bag and closed the slit that I had made with some glue. Unfortunately my efforts interferred with the instincts of the spider for on the following morning I found her enjoying a breakfast consisting of her own eggs and young spiders.

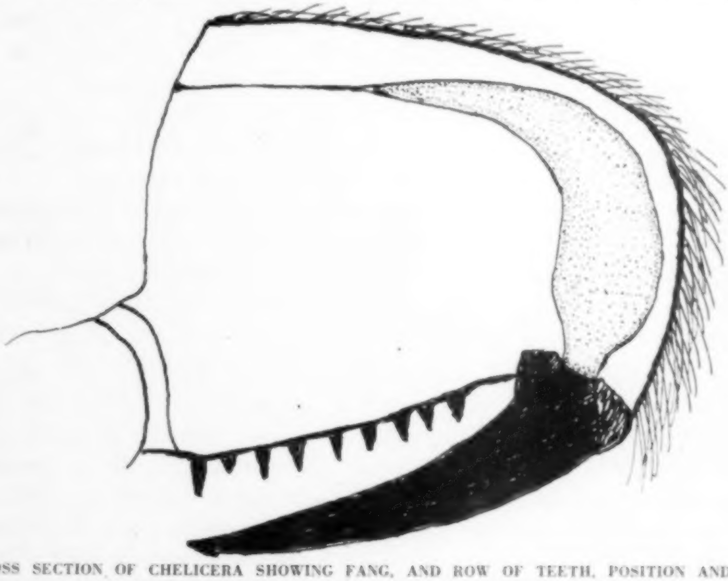
It is well known that tarantulas, in fact all spiders in general, are cannibals. Thinking that I might get some more detailed information on this particular habit, I placed two large females, that had just been brought in from their natural homes, under a large bell jar. Contrary to what might be expected, they were quite peaceable. One sitting quietly on one side of the jar, the other opposite her, behaving much like two persons not on speaking terms. This attitude they steadfastly maintained in spite of my efforts to bring them together. Thus they remained from nine o'clock in the morning till noon, when I left the laboratory. However during my absence, at least one of them must have realized that it was lunch time. On my return at about one o'clock P. M. I found one of the females sitting comfortably on the abdomen of the other and busily feeding on its contents. There was no evidence of any struggle. The dead tarantula was badly torn on the upper surface of the abdomen, but showed no other injury. The victor showed no evidence whatsoever of having been attacked.

It we may judge from these observations, there seems to be no definite fighting spirit. Several individuals apparently tolerate each other till one develops a desire for food.

Recently when an intelligent young man told me that his brother had been bitten by a tarantula and had died as a result a few days later, I decided to make some sort of a study of the effects of the much-dreaded venom.

Accordingly a guinea pig, seven months old and weighing about 635 grams was secured and the experiment was carried out in the following manner. The hair on the inside of the right hind leg

was cut off close to the skin, and then having fastened the leg and holding the pig firmly an attempt was made to have the tarantula implant her fangs on the prepared spot. The spider used in these tests was a large female, whose body measured 2½ inches in length and 1 inch across the thorax. After several attempt it became obvious that she was unable to penetrate the skin of the pig. Consequently in an effort to obtain some evidence on the nature of the poison, the chosen spot on the leg was disinfected with alcohol and treated so as to remove the difficulty in penetration. Hereupon after a little agitation the tarantula proceeded to implant both fangs well into the flesh of the guinea pig's leg. A second trial was made and in this, one of the fangs entered the flesh. Both times when the tarantula struck the guinea pig gave evidence of more or less pain. A number of observations on temperature,



CROSS SECTION OF CHELICERA SHOWING FANG, AND ROW OF TEETH, POSITION AND RELATIVE SIZE OF POISON GLAND. ENLARGED ABOUT TEN TIMES

respiration, etc., were made; but as all of these proved to be of obviously little value, they are omitted here. There developed a slight swelling in the leg which possibly was due mainly to the preparatory treatment. At no time did the guinea pig refuse to use the leg in walking around.

For the next subject I selected a white rat, about one month old. The tender skin of this animal was an advantage, for the tarantula was easily induced to implant her fangs deeply into the flesh of the inside of the right hind leg, and without any difficulty repeated the act. The four spots where the fangs had penetrated

assumed a reddish appearance; but the blood did not gather in a drop. When the tarantula struck, the rat struggled and gave other evidence of more or less pain.

Since the rat gave apparently a definite response to the effects of the poison, the observations are given here in condensed form. At first, immediately after the tarantula had struck, the rat seemed bewildered. With eyes closed it ran about in the cage holding up the wounded leg. After about 15 minutes it ceased to run and for a half an hour it jumped around in a jerky way. Then it seemed to go into a state of coma. For a half an hour it remained rather quiet with only a sudden movement of the legs now and then. During the two hours following the rat moved about restlessly, holding the wounded leg close to the body. Later it became quiet again and soon began using the wounded leg. Four hours from the time it was bitten the rat opened its eyes and an hour later it behaved as if it had entirely recovered. After several hours it partook of a hearty meal consisting of milk and corn meal.

According to a theory held by nutrition chemists a full-grown rat represents in many ways one thirtieth of a grown man. That is to say that a man requires thirty times the amount of food needed for a rat, etc. Assuming that a man would also require thirty times the amount of spider venom in order to suffer the same agony; I decided to try the "deadly" poison on myself.

On the morning of August 10, I induced the large tarantula, used in the previous tests, to strike me twice on the inside of the small finger of the left hand. In the first attempt the fangs barely penetrated the skin. The second was more successful, at least one of the fangs went well under the skin just below the first joint.

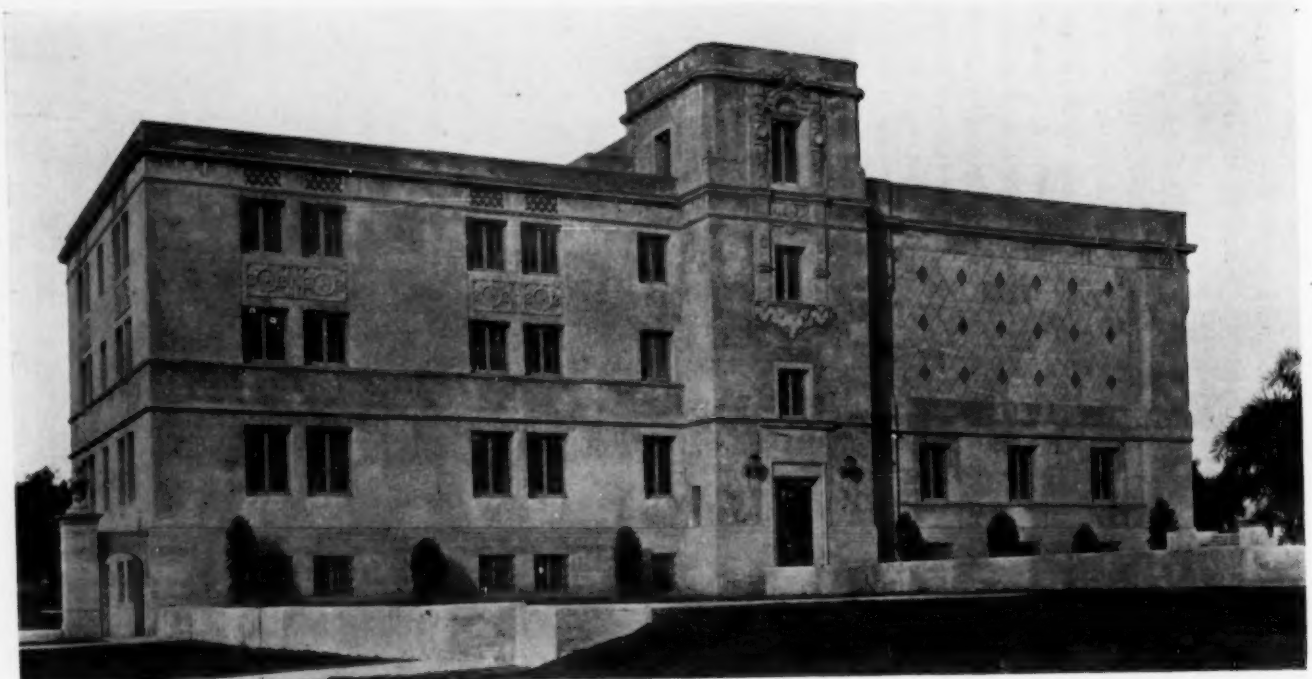
The blood gathered a little in the openings but did not collect in drops. A small amount of the poison, a clear, colorless, and tasteless liquid, was present in all four places where the fangs had struck. The sensation produced by the strike was that of a stab of a pin. This pain, if I may call it a pain, decreased gradually so that two hours after the biting took place no trace of the pain remained. At no time was the finger at all stiff.

On the following day the experiment was repeated. An effort to use another tarantula than the big one used in the previous tests failed, she could not be induced to strike, in spite of all teasing and with fangs conveniently placed on the tender portion of the small finger. So the large female was again brought out and she did not disappoint me. After but little teasing she struck violently twice. At the first strike I felt a strong desire to groan, at the second, in which the spider seemed even more desperate,

she broke her left fang off at the middle. The poison was used more generously than on the day before, two large drops collected and ran down on both sides of the finger. In one of the punctures a small drop of blood collected, the others merely assumed a reddish color.

The pain was very much as has been noted for the previous test, at first fairly sharp and then becoming gradually dull till in about two hours all trace of pain had disappeared.

It should be added that I did not resort to the use of any disinfectants, in fact the punctures were not tampered with in any way. With regard to relative susceptibility to insect poisons, I should probably be considered an average individual. The sting of a bee causes moderate swelling and a pain that lasts for ten or fifteen minutes.



NORMAN BRIDGE LABORATORY OF PHYSICS

California Institute of Technology, Pasadena, California, which was recently dedicated. It is here that Professor R. A. Millikan and his associates are carrying on their important work on the constitution of matter. Professor Millikan is working in close cooperation with Professor Noyes of the Gates chemical laboratory and the astronomers of the Mt. Wilson Observatory. Professor H. A. Lorenz said at the dedication: "If some effect cannot be found on the earth the astronomers will look for it in the sun and if there is some new and not wholly understood phenomenon in solar physics, it will be reproduced and investigated in the Norman Bridge Laboratory."

THE PROGRESS OF SCIENCE[1]

STARS AND MOLECULES

THE range of research has been expanded in opposite directions and has opened up two hitherto unattainable regions, the minutest and greatest, the constitution of the atom and the constitution of the stellar universe. The two extremes meet in the method of investigation for the laboratory and the observatory have gone into partnership. The variations in the movement of the electrons in their orbits about the nucleus reveal the chemical relationships and reactions of the elements as well as the age and motions of the stars.

The laws that have proved useful in explaining the properties of gases are now found useful in interpreting the sidereal system. Dr. F. H. Seares, in a recent address at the Carnegie Institution of Washington, showed that the gas law of the equipartition of energy applied in general to the stars. The massive stars have the lowest velocities, while the smaller stars move more rapidly. Professor Seares says: "This equal distribution of the energy of motion can scarcely hold rigorously for the stars, since such a state can exist only when the motions are completely at random, which is not the case with the stars. Some of them move as groups, having motions which are parallel and equal. That it holds even approximately is surprising, for in a gas the state of equipartition is brought about by the collisions and close encounters of the molecules. But the stars do not collide, or at least so rarely that in practice we may consider that their motions take place without mutual interference. How then has the equal distribution of energy among the stars come about? We do not know; but obviously its existence is a circumstance that must be considered in any theory which pretends to account for the development of the stellar universe."

This peculiar behavior of the stars results from an extensive investigation of the masses, densities, and diameters of stars of all classes by Professor Seares, combined with recent measures of stellar velocity by Dr. W. S. Adams and his associates at Mount Wilson Observatory. When the stars are classified according to their intrinsic brightness or candle power and their temperature, it is found, as first shown by Hertzsprung and Russell, that the hottest stars do not differ widely in intrinsic brightness, but that among the cooler stars—those which are red—there are enormous differences in luminosity, amounting to 10,000 fold or more. And, what is more extraordinary, there is a gap between the two extremes of brightness, within which we find no red stars at all. We thus have the so-called giant and dwarf subdivisions of stars, a grouping which shows most clearly among the stars of lowest temperature, but persists to some degree through all the intermediate temperatures and disappears only in the case of the bluish white stars of high temperature.

The classification according to intrinsic brightness and temperature thus reveals two great divisions of stars, both of which run through the entire scale of temperatures: the giants which, roughly, are of the same order of brightness, all very luminous; and the dwarfs which merge with the giants among the very hot stars, but become fainter and fainter as we run down the temperature scale. Our sun is a typical

[1] Edited by Watson Davis, Science Service.

dwarf star of intermediate temperature, whose brightness is about 1/100 that of an average giant.

The study of astronomical processes in terrestrial laboratories has been made possible by the use of heavy currents of electricity. Dr. Gerald L. Wendt has by this means heated thin tungsten wires to the temperature of the hottest stars, some 50,000° F. and reports to the Chicago Section of the American Chemical Society and to the National Academy of Sciences that the metal is decomposed almost completely into helium. This, if true, would be a more complete and extensive disruption of the atoms than has been attained by Sir Ernest Rutherford, of the Cavendish Laboratory, Cambridge, who has obtained traces of hydrogen by bombarding the nucleus of nitrogen and other elements of low atomic weight with alpha particles.

Professor R. A. Millikan, of the California Institute of Technology, is also studying the constitution of atoms by bombarding with alpha particles, using his oil-drop detector to catch and count the ejected electrons. His method is to suspend in such a field a minute oil-drop, of diameter about one hundred thousandth of an inch, giving it just enough charge to neutralize the force of gravity upon it and therefore to keep it just suspended in midair tending to move neither up nor down. He then shoots alpha rays immediately underneath the drop and when one of these rays goes through a helium atom which is also underneath the drop and detaches from it an electron, the residue of this atom becomes thereby electrically charged and is thrown instantly upward by the field into the oil drop to which it sticks, thereby communicating its charge to that of the drop and changing the balance of the forces which had theretofore acted upon the drop. The result is that the drop begins to move upward at a speed which is proportional to the amount of charge communicated to it by the advent of the atom of helium upon it, so that if the alpha particle knocked out just one electron from the helium atom, the oil drop which instantly caught that ionized atom would begin to move upward with a speed which would be proportional to the value of this single electronic charge. But if the alpha particle had the good fortune to pick off both electrons from the helium atom as it shot through it, the charge communicated to the oil drop by the capture of the residue of the helium atom would then be twice as large as before and the motion would therefore be twice as rapid. By catching in this way the residues of ionized helium atoms at practically the instant at which they become ionized, it is possible to tell without the slightest uncertainty whether the alpha particle in shooting through the atom has knocked off just one of its electrons or both of them.

The results of Dr. Millikan's experiment are very interesting. He found that his alpha particles, which, it will be remembered, are moving with a speed very much faster than that of an ordinary bullet, *got both electrons every sixth shot*. That is to say, five shots out of six which got anything knocked only one of the two electrons out of the helium atom, but *on an average every sixth* successful shot knocked them both out. These facts throw some light on the structure of the helium atom, for they show that the two electrons in their revolutions around the nucleus of the helium atom must get into the same region of the atom a considerable portion of the time, otherwise they could not both get into the way of the alpha particle bullets as frequently as they are found to do. It is also interesting that Dr. Millikan has not yet found any atom save the helium atom, which loses more than one single electronic charge when an alpha particle is shot through it.

AN INTERNATIONAL LANGUAGE

THERE is a conflict between the political and scientific tendencies of the times and it will be curious to watch which influence prevails. In the political field nationalism is the order of the day. The war gave birth to a dozen new nations. International intercourse is hampered by tariff barriers, postal impediments and the revival of obsolescent languages.

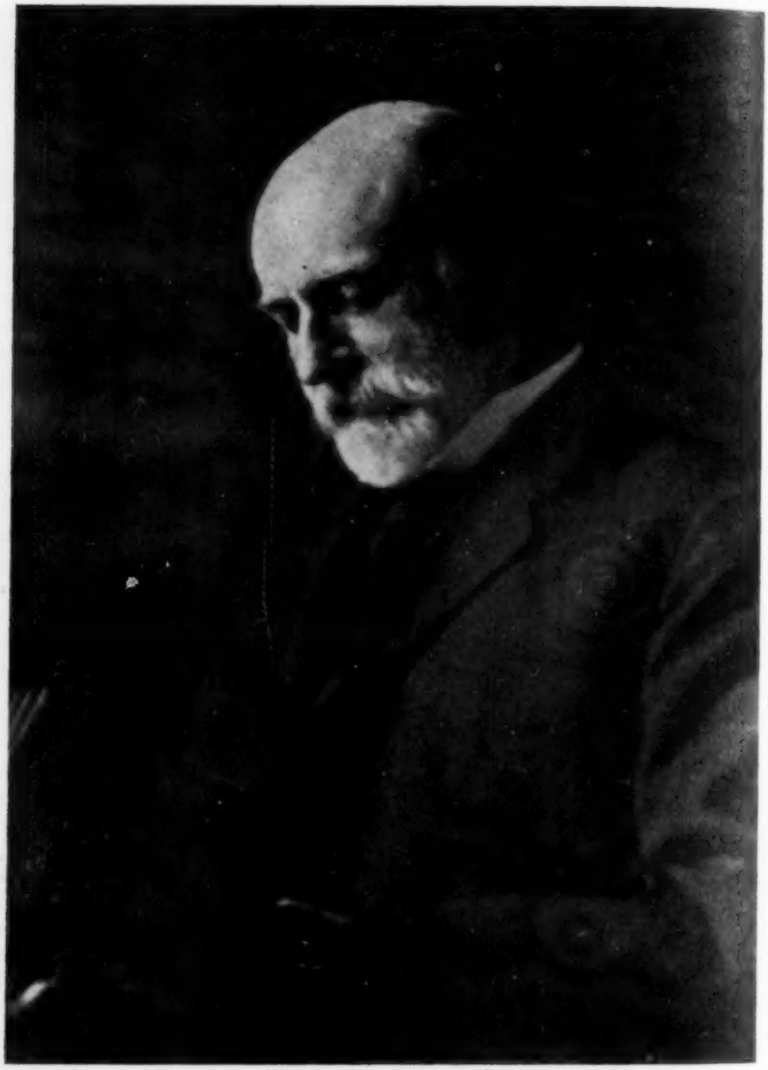
But now comes the radio which knows no nationality and which may put a girdle round the earth seven times a second. It is impossible to partition the ether. Its waves spread impartially in all directions and anybody may listen in without the consent or knowledge of the sender. The Eiffel tower talks to people of thirty tongues. So long as intercommunication was confined to print, mail and telegraph, it was possible to get along with the aid of interpreters, but when millions are receiving messages without intermediaries they must have a common language. Whether this will be gradually and capriciously evolved out of the current commercial and maritime codes; whether the nations may set aside their mutual jealousy so far as to adopt one of the modern languages; whether Latin, the old international language, will be brought into use in its classical, ecclesiastical or a simplified form; or whether an artificial language, such as Esperanto or Ido, will find acceptance, remains to be seen. It is no longer an academic question, but has suddenly become of pressing practical importance. It should receive serious attention by competent philologists. It is of peculiar importance to the scientist who formerly could get along fairly well with a reading knowledge of English, French and German but who now must master not only Italian, Russian, Dutch and the Scandinavian languages, but also Polish, Czech, Japanese, Chinese, Irish and Hebrew if he wants to read the reports of research in the original. Patriotic pride is strong in the newer nations and demands the publication of their scientific achievements in the vernacular. But the more powerful the impulse for the multiplication of languages and the wider the fields in which science is cultivated, the more necessary will become an international medium of communication.

The whole progress of civilization during the past century and a half has been toward making the world a smaller place to live in. Railroad, electric line, automobile, airplane and airship have all made transportation of concrete things easier and faster. The wire telegraph and telephone and the radio telegraph and telephone have taken information instantaneously to the whole world.

There is a missing link in this great time-contraction of the globe. The Japanese trans-Pacific radio operator can, in international code, tell the American operator that atmospheric disturbances are interfering with communication; they can hold a rather extended technical conversation in code. But difference in language prevents the simplest kind of exchange of ordinary information between many peoples of different countries, in spite of the fact that mechanical means of communication are highly developed.

International language will soon become an acknowledged world necessity. Like all the other great developments of modern times, it must first undergo development and scientific study. An international auxiliary language that will bring people of alien tongues together is not a remote possibility. If it existed to-day, if the generation that is growing up to-day were being taught an accepted international language, there is little question but that the next generation of the world would be able to easily "listen in" on radio broadcasting from any nation.

Pioneer work in the scientific con-



JOHN CASPER BRANNER
Formerly professor of geology at Stanford University and at the time of his death president emeritus.

sideration of the international auxiliary language problem is being done by the Committee on an International Auxiliary Language of the International Research Council, headed by Dr. F. G. Cottrell. Much progress is being made as those who attended the symposium on the subject at the Toronto meeting of the American Association for the Advancement of Science know.

INTERNATIONAL MEETINGS AT ROME

THE International Research Council, organized in 1919 at Brussels, will meet again in that city on July 18 of this year. Meanwhile the International Astronomical Union and the International Geodetic and Geophysical Union will meet at Rome on May 2. The United States will be represented at the astronomical meeting by Professor Frank Schlesinger, Yale University, chairman of the American delegates; Dr. R. G. Aitken, Lick Observatory; Dr. C. E. St. John and Professor F. H. Seares, Mount Wilson Observatory; Dr. H. D. Curtis, director of the Allegheny Observatory; Dr. O. J. Lee, Yerkes Observatory; Professor H. N. Russell, Princeton University; Professor John A. Miller, Swarthmore College; Professor Edward Kasner, Columbia University; Dr. Harlow Shapley, director of the Harvard College Observatory, and Dr. Frank B. Littell, of the U. S. Naval Observatory.

Dr. William Bowie, chief of the division of geodesy of the U. S. Coast and Geodetic Survey, will head the American delegation to the geodetic and geophysical meeting, and will be delegate to the section on geodesy. Other delegates are: Section on terrestrial magnetism, Dr. L. A. Bauer, director of the department of terrestrial magnetism of the Carnegie Institution of Washington; section of seismology, Professor H. F. Reid, of the Johns Hopkins University; section on meteorology, Dr. H. H. Kimball, of the U. S. Weather Bureau; section on physical oceanography, Dr. G. W. Littlehales, of the hydrographic office of the Navy Department; section on volcanology, Dr. H. S. Washington, of the geophysical laboratory of the Carnegie Institution of Washington.

American astronomers met in Washington just before the American astronomical delegates left for Rome and considered many of the subjects that will come up for international consideration.

One of the questions on the agenda of the Rome meeting that will interest and affect the ordinary person most directly is the reform of the calendar. The American section did not instruct its delegates on this matter but it is expected that some action will be taken by the International Astronomical Union meeting. Much of the discussion by astronomers at Rome will relate to the unification of nomenclature and plans for international cooperation in various projects. A new system of spectrum classification of stars will be recommended by the American delegates, and plans for the determination of terrestrial longitude by wireless telegraphy will be laid. Another important question that will arise is the variation of latitude, or the "wabbling" of the earth. About twenty years ago, the Ukiah, Calif., Observatory was established as one of five latitude stations, and valuable data have been obtained. But the astronomers realize the need of further knowledge of the factors that affect the accuracy of their measurements and will urge additional stations.

Each one of the sections of the International Geodetic and Geophysical Unions has full agendas. The scientists of Europe will discuss the triangulation nets of many of their countries and Africa, as well as the establishment of a fundamental longitude net of the world. Euro-

peans will have as an example of international cooperation the United States, Mexico and Canada which are using the same triangulation net with effective results. Isostasy, or the distribution of densities of the earth, will also be considered. Volcanologists will lay plans for getting to the eruptions in the least possible time and they will also arrange to chart the volcanoes that discharge their lava into the sea instead of the air and for this reason are seldom discovered. They will consider tapping the volcanic energy of the earth by holes leading down into the hot portions, as is now being done in Italy. Equally interesting questions will be discussed by those who study the earth's magnetism, earthquakes and the oceans.

The International Union of Pure and Applied Chemistry meets at Lyons, France, from June 28 to July 2. From August 10 to 19 there will be an International Geological Congress at Brussels, Belgium. In June there will be an International Chemical Conference at Utrecht, Holland, to which distinguished chemists of all nations, including Germany and Russia, have been invited. Professor W. A. Noyes is acting as chairman of the committee to select American members of the conference, the other members being Professor Stieglitz, Professor Lewis and Dr. Whitney.

SCIENTIFIC ITEMS

We record with regret the death of Benjamin Moore, Whitney professor of biochemistry at the University of Oxford and formerly professor of physiology at Yale University; of Augustus D. Waller, professor of physiology at the University of London; of Theodor Liebisch, professor of mineralogy at Berlin; and of Camille Jordan, professor of mathematics at Paris and editor of the *Journal de Mathématiques*.

Sir Ernest Rutherford, Cavendish professor of experimental physics in the University of Cambridge, has been named as president of the British Association for the Advancement of Science for the annual meeting to be held at Liverpool next year.—Sir Frank Dyson was elected president of the British Optical Society at the annual meeting. At the same meeting Professor A. A. Michelson, of the University of Chicago, and Dr. M. von Rohr, of Messrs. Carl Zeiss, Jena, were elected honorary fellows of the society.

Professor Albert Einstein, of the University of Berlin, has delivered a series of four lectures in Paris on the "Theory of Relativity," under the auspices of the Collège de France.—After Vilhjalmur Stefansson had delivered a lecture before the National Geographic Society, the society made the announcement that its Research Council had awarded him the Grant Squires prize "in recognition of the unique interest and importance of his book, 'The Friendly Arctic,' the outstanding geographic publication of 1921."

Establishment of fellowships in medicine to increase the supply of qualified teachers and investigators is announced by the National Research Council. The fellowships, supported by appropriations of the Rockefeller Foundation and the General Education Board, will be open to Americans or Canadians of either sex holding or qualified to hold degrees of doctor of medicine or doctor of philosophy from approved universities. The appropriations are $100,000 a year for five years. Successful candidates, to be known as fellows in medicine of the National Research Council, will be at liberty to choose the institutions or universities in which they will work. The fellowships in medicine are similar to the fellowships in physics and chemistry established under the same auspices.